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AN
ENCYCLOPÆDIA
OF
ARCHITECTURE.

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AN
ENCYCLOPÆDIA
OF
ARCHITECTURE,
HISTORICAL, THEORETICAL, AND PRACTICAL.

BY

JOSEPH GWILT.

ILLUSTRATED WITH MORE THAN ONE THOUSAND ENGRAVINGS ON WOOD

BY R. BRANSTON,

FROM

DRAWINGS BY JOHN SEBASTIAN GWILT.

LONDON:
LONGMAN, BROWN, GREEN, AND LONGMANS,
PATERNOSTER ROW.
MDCCCXLII.

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PREFACE.

An Encyclopædia of any of the fine arts has, from its nature, considerable advantage over one which relates to the sciences generally. In the latter, the continual additions made to the common stock of knowledge frequently effect such a complete revolution in their bases and superstructure, that the established doctrines of centuries may be swept away by the discoveries of a single day. The arts, on the other hand, are founded upon principles unsusceptible of change. Fashion may, indeed,—nay, often does,—change the prevailing taste of the day, but first principles remain the same; and as, in a cycle, the planets, after a period of wandering in the heavens, return to the places which they occupied ages before, so, in the arts, after seasons of *extravaganza* and *bizzaria*, a recurrence to sound taste is equally certain.

It is unfortunate for the productions of the arts that the majority of those who are constituted their judges are so little qualified for the task, either by education or habits; but on this, as it has been the complaint of every age, it is perhaps useless to dwell. This much may be said, that before any one can with propriety assume the name of architect, he must proceed regularly through some such course as is prescribed in this work. The main object of its author has been to impart to the *student* all the knowledge indispensable for the exercise of his profession; but should the perusal of this encyclopædia serve to form, guide, or correct, the taste even of the mere *amateur*, the author will not consider that he has laboured in vain.

An encyclopædia is necessarily a limited arena for the exhibition of an author's power; for although every subject in the department of which it treats must be noticed, none can be discussed so extensively as in a separate work. An attempt to produce a *Complete Body of Architecture* the author believes to be entirely original. In his celebrated work, *L'Art de Batir*, Rondelet has embodied all that relates to the construction of buildings. Durand, too, (*Leçons et Précis d'Architecture*,) has published some admirable rules on composition and on the graphic portion of the art. Lebrun (*Théorie d'Architecture*) has treated on the philosophy of the equilibrium, if it may be so called, of the orders. The *Encyclopédie Méthodique* contains, under various heads, some invaluable detached essays, many of which, however, suffer from want of the illustrative plates which were originally projected as an appendage to them. All these, with others in the French language, might, indeed, be formed into a valuable text-book for the architect; but no such attempt has hitherto been made. Neither in Germany nor in Italy has any complete work of the kind appeared. In the English, as in other languages, there are doubtless several valuable treatises on different branches of the art, though not to the same extent as in French. In 1756, Ware (London, folio) published what he called *A Complete Body of Architecture.* This, though in many respects an useful work, is far behind the wants of the present day. It is confined exclusively to Roman and Italian architecture; but it does not embrace the history even of these branches, nor does it contain a word on the sciences connected with construction. The details, therefore, not being sufficiently carried out, and many essential branches being entirely omitted, the work is not so generally useful as its name would imply. From these authorities, and many others, besides his own resources, the author of this encyclopædia has endeavoured to compress within the limits of one closely-printed volume all the elementary knowledge indispensable to the student and amateur; and he even ventures to indulge the belief that it will be found to contain information which the experienced professor may have overlooked.

Though, in form, the whole work pretends to originality, this pretension is not advanced for the whole of its substance. Not merely all that has long been known, but even the progressive discoveries and improvements of modern times, are usually founded on facts which themselves have little claims to novelty. As a fine art, architecture, though in its applications and changes inexhaustible, is in respect of first principles confined within certain limits; but the analysis of those principles and their relation to certain types have afforded some views of the subject which, it is believed, will be new even to those who have passed their lives in the study of the art.

In those sciences on which the constructive power of the art is based, the author apprehended he would be entitled to more credit by the use of weightier authorities than his own. Accordingly, in the Second Book, he has adopted the algebra of Euler; and in other parts, the works of writers of established reputation. The use of Rossignol's geometry may indeed be disapproved by rigid mathematicians; but, considering the variety of attainments indispensable to the architectural student, the author was induced to shorten and smooth his path as much as possible, by refraining from burdening his memory with more mathematical knowledge than was absolutely requisite for *his* particular art. On this account, also, the instruction in algebra is not carried beyond the solution of cubic equations: up to that point it was necessary to prepare the learner for a due comprehension of the succeeding inquiries into the method of equilibrating arches and investigating the pressures of their different parts.

In all matters of importance, in which the works of previous writers have been used, the sources have been indicated, so that reference to the originals may be made. Upon the celebrated work of Rondelet above mentioned, on many learned articles in the *Encyclopédie Méthodique,* and on the works of Durand and other esteemed authors, large contributions have been levied; but these citations, it will be observed, appear for the first time in an English dress. In that part of the work which treats of the doctrine of arches, the chief materials, it will be seen, have been borrowed from Rondelet, whose views the author has adopted in preference to those he himself gave to the world many years ago, in a work which passed through several editions. Again, in the section on shadows, the author has not used his own treatise on Sciography. In the one case, he is not ashamed to confess his inferiority in so important a branch of the architect's studies; and in the other, he trusts that matured experience has enabled him to treat the subject in a form likely to be more extensively useful than that of treading in his former steps.

The sciences of which an architect should be cognisant are enumerated by Vitruvius at some length in the opening chapter of his first book. They are, perhaps, a little too much swelled, though the Roman in some measure qualifies the extent to which he would have them carried. "For," he observes, "in such a variety of matters" (the different arts and sciences) "it cannot be supposed that the same person can arrive at excellence in each." And again: "That architect is sufficiently educated whose general knowledge enables him to give his opinion on any branch when required to do so. Those unto whom nature hath been so bountiful that they are at once geometricians, astronomers, musicians, and skilled in many other arts, go beyond what is required by the architect, and may be properly called mathematicians in the extended sense of that word." Pythius, the architect of the temple of Minerva at Priene, differed, however, from the Augustan architect, inasmuch as he considered it absolutely requisite for an architect to have as accurate a knowledge of all the arts and sciences as is rarely acquired even by a professor devoted exclusively to one.

In a work whose object is to compress within a comparatively restricted space so vast a body of information as is implied in an account of what is known of historical, theoretical, and practical architecture, it is of the highest importance to preserve a distinct and precise arrangement of the subjects, so that they may be presented to the reader in consistent order and unity. Without order and method, indeed, the work, though filled with a large and valuable stock of information, would be but an useless mass of knowledge. In treating the subjects in detail, the alphabet has not been made to perform the function of an index, except in the glossary of the technical terms, which partly serves at the same time the purpose of a dictionary, and that of an index to the principal subjects noticed in the work. The following is a synoptical view of its contents, exhibiting its different parts, and the mode in which they arise from and are dependent on each other.

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12. Painting and Gilding.
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Perfection is not attainable in human labour, and the errors and defects of this work will, doubtless, in due time be pointed out; but as the subject has occupied the author's mind during a considerable practice, he is inclined to think that these will not be very abundant. He can truly say that he has bestowed upon it all the care and energy in his power; and he alone is responsible for its errors or defects; — the only assistance he has to acknowledge being from his son, Mr. John Sebastian Gwilt, by whom the illustrative drawings were executed. No apology is offered for its appearance, inasmuch as the want of such a book has been felt by every architect at the beginning of his career. Not less is wanted a similar work on Civil Engineering, which the author has pleasure in stating is about to be shortly supplied by his friend, Mr. Edward Cresy.

Without deprecating the anger of the critic, or fearing what may be urged against his work, the author now leaves it to its fate. His attempt has been for the best, and he says with sincerity,

> ——————— "Si quid novisti rectius istis
> Candidus imperti, si non his utere mecum."

J. G.

Abingdon Street, Westminster,
30th September, 1842.

P.S.—The author begs here to acknowledge the unremitting zeal of the printers of this work, and the obligations under which they have laid him by their care in its progress through the press. A few unavoidable errors have, however, occurred, notwithstanding every care; and the attention of the reader is requested to the "Errata" for their correction.

ERRATA.

Page 353. line 6. from bottom, *for* FM $=\frac{\times \mathrm{CP}}{\mathrm{CA}}-\mathrm{CA}$, *read* FM $=\frac{\mathrm{CF}\times\mathrm{CP}}{\mathrm{CA}}-\mathrm{CA}$.

400. line 4., *for* AA *read* AB.

403. last line, *for* $x=\sqrt{\frac{2p-2bc}{a}+{}^{bb}-\frac{b}{a}}$, *read* $x=\sqrt{\frac{2p-2bc}{a}+\frac{bb}{aa}}-\frac{b}{a}$.

404. line 3., *for* $x=\sqrt{\frac{163851\cdot56\times2-2128\times2\times12\frac{1}{2}}{195}+\frac{2128}{195}\times\frac{2128}{195}-\frac{2128}{195}}=28\cdot16$,

read $x=\sqrt{\frac{163851\cdot56\times2-2128\times2\times12\frac{1}{2}}{195}+\frac{2128}{195}\times\frac{2128}{195}}-\frac{2128}{195}=28\cdot16$.

414. in *fig.* 582., letter A omitted at springing of arch inside, and letter B at the outside of the springing.

421. line 1., *for* $x=\sqrt{\frac{2p}{f}+\frac{2pd+2nc-2mc}{af}}+\frac{b^2}{a^2f^2}-\frac{b}{af}$,

read $x=\sqrt{\frac{2p}{f}+{}^{2pd+2nc-2mc}+\frac{b^2}{a^2f^2}}-\frac{b}{af}$.

430. line 25. from bottom, *for* $\sqrt{49\frac{1}{2}\times49\frac{1}{2}+22\frac{1}{2}\times22\frac{1}{2}=54\frac{37}{100}}$,

read $\sqrt{49\frac{1}{2}\times49\frac{1}{2}+22\frac{1}{2}\times22\frac{1}{2}}=54\frac{37}{100}$.

432. line 5., *for* BC, *read* DC.

432. line 4. from bottom, *for* $\sqrt{14207=119 \text{ ft. } 2 \text{ in.}}$, *read* $\sqrt{14207}=119$ ft. 2 in.

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ARCHITECTURE.

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CHAP. I.

ON THE ORIGIN OF ARCHITECTURE.

Sect. I.

WANTS OF MAN, AND FIRST BUILDINGS.

1. Protection from the inclemency of the seasons was the mother of architecture. Of little account at its birth, it rose into light and life with the civilisation of mankind; and, proportionately as security, peace, and good order were established, it became, not less than its sisters, painting and sculpture, one method of transmitting to posterity the degree of importance to which a nation had attained, and the moral value of that nation amongst the kingdoms of the earth. If the art, however, be considered strictly in respect of its actual utility, its principles are restricted within very narrow limits; for the mere art, or rather science, of construction, has no title to a place among the fine arts. Such is in various degrees to be found among people of savage and uncivilised habits; and until it is brought into a system founded upon certain laws of proportion, and upon rules based on a refined analysis of what is suitable in the highest degree to the end proposed, it can pretend to no rank of a high class. It is only when a nation has arrived at a certain degree of opulence and luxury that architecture can be said to exist in it. Hence it is that architecture, in its origin, took the varied forms which have impressed it with such singular differences in different countries; differences which, though modified as each country advanced in civilisation, were, in each, so stamped, that the type was permanent, being refined only in a higher degree in their most important examples.

2. The ages that have elapsed, and the distance by which we are separated from the nations among whom the art was first practised, deprive us of the means of examining the shades of difference resulting from climate, productions of the soil, the precise spots upon which the earliest societies of man were fixed, with their origin, number, mode of life, and social institutions; all of which influenced them in the selection of one form in preference to another. We may, however, easily trace in the architecture of nations, the types of three distinct states of life, which are clearly discoverable at the present time; though in some cases the types may be thought doubtful.

Sect. II.

ORIGIN AND PROGRESS OF BUILDING.

3. The original classes into which mankind were divided were, we may safely assume, those of hunters, of shepherds, and of those occupied in agriculture; and the buildings for protection which each would require, must have been characterised by their several occupations. The hunter and fisher found all the accommodation they required in the clefts and caverns of rocks; and the indolence which those states of life induced, made them insensible or indifferent to greater comfort than such naturally-formed habitations afforded. We are certain that thus lived such tribes. Jeremiah (chap. xlix. 16.), speaking of the judgment upon Edom, says, "O thou that dwellest in the clefts of the rock, that holdest the height of the hill;" a text which of late has received ample illustration from travellers, and especially from the labours of Messrs. Leon de Laborde and Linant, in the splendid engravings of the ruins of Petra (*fig.* 1.). To the shepherd, the inhabitant of the plains wandering from one spot to another, as pasture became inadequate to the support of his flocks, another species of dwelling was more appropriate; one which he could remove with him in his wanderings: this was the tent, the type of the architecture of China, whose people were, like all the Tartar races, *nomades* or *scenites*, that is, shepherds or dwellers in tents. Where a portion of the race fixed its abode for the purposes of agriculture, a very different species of dwelling was necessary. Solidity was required as well for the personal comfort of the husbandman as for preserving, from one season to another, the fruits of the earth, upon which he and his family were to exist. Hence, doubtless, the hut, which most authors have assumed to be the type of Grecian architecture.

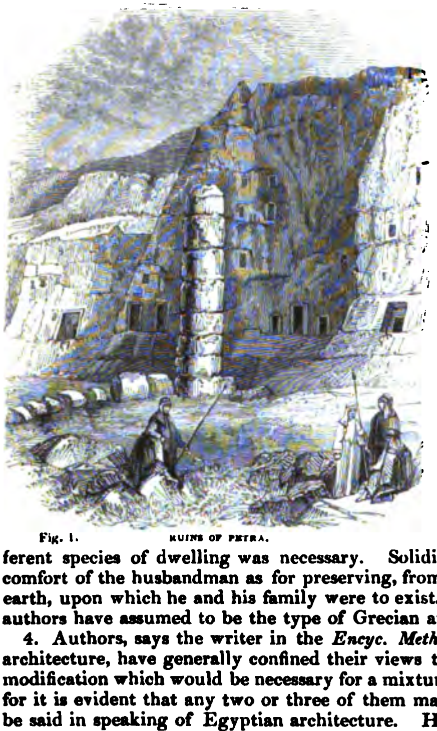


Fig. 1. RUINS OF PETRA.

4. Authors, says the writer in the *Encyc. Methodique*, in their search after the origin of architecture, have generally confined their views to a single type, without considering the modification which would be necessary for a mixture of two or more of the states of mankind; for it is evident that any two or three of them may co-exist, a point upon which more will be said in speaking of Egyptian architecture. Hence have arisen the most discordant and contradictory systems, formed without sufficient acquaintance with the customs of different people, their origin, and first state of existence.

5. The earliest habitations which were constructed after the dispersion of mankind from the plains of Sennaar (for there, certainly, as we shall hereafter see, even without the evidence of Scripture, was a great multitude gathered together), were, of course, proportioned to the means which the spot afforded, and to the nature of the climate to which they were to be adapted. Reeds, canes, the branches, bark, and leaves of trees, clay, and similar materials would be first used. The first houses of the Egyptians and of the people of Palestine were of reeds and canes interwoven. At the present day the same materials serve to form the houses of the Peruvians. According to Pliny (l. vii.), the first houses of the Greeks were only of clay; for it was a considerable time before that nation was acquainted with the process of hardening it into bricks. The Abyssinians still build with clay and reeds. Wood, however, offers such facilities of construction, that still, as of old, where it abounds, its adoption prevails. At first, the natural order seems to be that which Vitruvius describes in the first chapter of his second book. "The first attempt," says our author, "was the mere erection of a few spars, united together with twigs, and covered with mud. Others built their walls of dried lumps of turf, connected these walls together by means of timbers laid across horizontally, and covered the erections with reeds and boughs, for the purpose of sheltering themselves from the inclemency of the seasons. Finding, however, that flat coverings of this sort would not effectually shelter them in the winter season, they made their roofs of two inclined planes, meeting each other in a ridge at the summit, the whole of which they covered with clay, and thus carried off the rain." The same author

afterwards observes, "The woods about Pontus furnish such abundance of timber, that they build in the following manner. Two trees are laid level on the earth, right and left, at such distance from each other as will suit the length of the trees which are to cross and connect them. On the extreme ends of these two trees are laid two other trees, transversely: the space which the house will enclose is thus marked out. The four sides being so set out, towers are raised, whose walls consist of trees laid horizontally, but kept perpendicularly over each other, the alternate layers yoking the angles. The level interstices, which the thickness of the trees alternately leave, is filled in with chips and mud. On a similar principle they form their roofs, except that gradually reducing the length of the trees which traverse from angle to angle, they assume a pyramidal form. They are covered with boughs, and thus, after a rude fashion of vaulting, their quadrilateral roofs are formed." The northern parts of Germany, Poland, and Russia still exhibit traces of this principle of building; and they are also found in Florida, Louisiana, and elsewhere, in various places. See *fig.* 2.

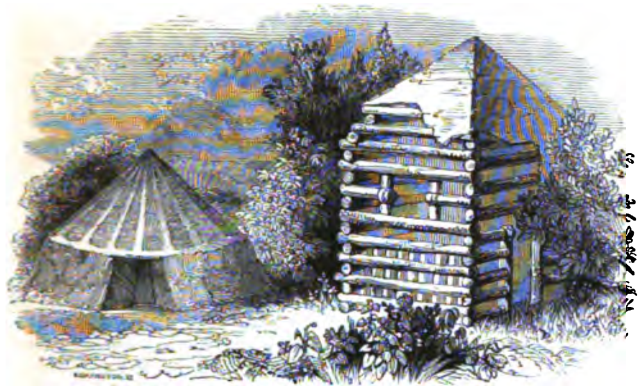


Fig. 2. EARLY TIMBER CONSTRUCTION.

6. We shall not, in this place, pursue the discussion on the timber hut, which has certainly, with great appearance of probability, been so often said to contain within it the types of Grecian architecture, but shall, under that head, enlarge further on the subject.

Sect. III.

DIFFERENT SORTS OF DWELLINGS ARISING FROM DIFFERENT OCCUPATIONS.

7. The construction of the early habitations of mankind required little skill and as little knowledge. A very restricted number of tools and machines was required. The method of felling timber, which uncivilised nations still use, namely, by fire, might have served all purposes at first. The next step would be the shaping of hard and infrangible stones into cutting tools, as is still the practice in some parts of the continent of America. These, as the metals became known, would be supplanted by tools formed of them. Among the Peruvians, at their invasion by the Spaniards, the only tools in use were the hatchet and the adze; and we may fairly assume that similar tools were the only ones known at a period of high antiquity. The saw, nails, the hammer, and other instruments of carpentry were unknown. The Greeks, who, as Jacob Bryant says, knew nothing of their own history, ascribe the invention of the instruments necessary for working materials to Dædalus; but only a few of these were known even in the time of Homer, who confines himself to the hatchet with two edges, the plane, the auger, and the rule. He particularises neither the square, compasses, nor saw. Neither the Greek word πριων (a saw), nor its equivalent, is to be found in his works. Dædalus is considered, however, by Goguet as a fabulous person altogether, the word meaning, according to him, nothing more than a skilful workman, a meaning which, he observes, did not escape the notice of Pausanias. The surmise is borne out by the non-mention of so celebrated a character, if he had ever existed, by Homer, and, afterwards, by Herodotus. The industry and perseverance of man, however, in the end, overcame the difficulties of construction. For wood, which was the earliest material, at length were substituted bricks, stone, marble, and the like; and edifices were reared of unparalleled magnificence and solidity. It seems likely, that bricks would have been in use for a considerable period before stone was employed in building. They were, probably, after moulding, merely subjected to the sun's rays to acquire hardness. These were the materials whereof the Tower of Babel was constructed. These also, at a very remote period, were used by the Egyptians. Tiles seem to have been of as high an antiquity as bricks, and to have been used, as in the present day, for covering roofs.

8. The period at which wrought stone was originally used for architectural purposes is

quite unknown, as is that in which cement of any kind was first employed as the medium of uniting masonry. They were both, doubtless, the invention of that race which we have mentioned as cultivators of land, to whom is due the introduction of architecture, properly so called. To them solid and durable edifices were necessary as soon as they had fixed upon a spot for the settlement of themselves and their families.

9. Chaldæa, Egypt, Phœnicia, and China are the first countries on record in which architecture, worthy the name, made its appearance. They had certainly attained considerable proficiency in the art at a very early period; though it is doubtful, as respects the three first, whether their reputation is not founded rather on the enormous masses of their works, than on beauty and sublimity of form. Strabo mentions many magnificent works which he attributes to Semiramis; and observes that, besides those in Babylonia, there were monuments of Babylonian industry throughout Asia. He mentions λόφοι (high altars), and strong walls and battlements to various cities, as also subterranean passages of communication, aqueducts for the conveyance of water under ground, and passages of great length, upwards, by stairs. Bridges are also mentioned by him (lib. xvi.). Moses has preserved the names of three cities in Chaldæa which were founded by Nimrod (*Gen.* x. 10.). Ashur, we are told, built Nineveh; and (*Gen.* xix. 4.) as early as the age of Jacob and Abraham, towns had been established in Palestine. The Chinese attribute to Fohi the encircling of cities and towns with walls; and in respect of Egypt, there is no question that in Homer's time the celebrated city of Thebes had been long in existence. The works in India are of very early date; and we shall hereafter offer some remarks, when speaking of the extraordinary monument of Stonehenge, tending to prove, as Jacob Bryant supposes, that the earliest buildings of both nations, as well as those of Phœnicia and other countries, were erected by colonies of some great original nation. If the Peruvians and Mexicans, without the aid of carriages and horses, without scaffolding, cranes, and other machines used in building, without even the use of iron, were enabled to raise monuments which are still the wonder of travellers, it would seem that the mechanical arts were not indispensable to the progress of architecture; but it is much more likely that these were understood at an exceedingly remote period in Asia, and in so high a degree as to have lent their aid in the erection of some of the stupendous works to which we have alluded.

10. The art of working stone, which implies the use of iron and a knowledge of the method of tempering it, was attributed to Tosorthus, the successor of Menes. It seems, however, possible that the ancients were in possession of some secret for preparing bronze tools which were capable of acting upon stone. Be that as it may, no country could have been called upon earlier than Egypt to adopt stone as a material, for the climate does not favour the growth of timber; hence stone, marble, and granite were thus forced into use; and we know that, besides the facility of transport by means of canals, as early as the time of Joseph waggons were in use. (*Gen.* xlv. 19.) We shall hereafter investigate the hypothesis of the architecture of Greece being founded upon types of timber buildings, merely observing here, by the way, that many of the columns and entablatures of Egypt had existence long before the earliest temples of Greece, and therefore that, without recurrence to timber construction, prototypes for Grecian architecture are to be found in the venerable remains of Egypt, where it is quite certain wood was not generally employed as a material, and where the subterranean architecture of the country offers a much more probable origin of the style.

CHAP. II.

ARCHITECTURE OF VARIOUS COUNTRIES.

Sect. I.

DRUIDICAL AND CELTIC ARCHITECTURE.

11. If rudeness, want of finish, and the absence of all appearance of art, be criteria for judgment on the age of monuments of antiquity, the wonderful remains of Abury and Stonehenge must be considered the most ancient that have preserved their form so as to indicate the original plan on which they were constructed. The late Mr. Godfrey Higgins, a gentleman of the highest intellectual attainments, in his work on the Celtic Druids (published 1829), has shown, as we think satisfactorily, that the Druids of the British Isles were a colony of the first race of people, learned, enlightened, and descendants of the persons who escaped the deluge on the borders of the Caspian Sea; that they were the earliest occupiers of Greece, Italy, France, and Britain, and arrived in those places by a route nearly

along the forty-fifth parallel of north latitude; that, in a similar manner, colonies advanced from the same great nation by a southern line through Asia, peopling Syria and Africa, and arriving at last by sea through the Pillars of Hercules at Britain; that the languages of the western world were the same, and that one system of letters — viz. that of the Irish Druids — pervaded the whole, was common to the British Isles and Gaul, to the inhabitants of Italy, Greece, Syria, Arabia, Persia, and Hindostan; and that one of the two alphabets (of the same system) in which the Irish MSS. are written — viz. the Beth-luis-nion — came by Gaul through Britain to Ireland; and that the other — the Bobeloth — came through the Straits of Gibraltar. Jacob Bryant thinks that the works called Cyclopean were executed at a remote age by colonies of some great original nation; the only difference between his opinion and that of Mr. Higgins being, that the latter calls them Druids, or Celts, from the time of the dispersion above alluded to.

12. The unhewn stones, whose antiquity and purport is the subject of this section, are found in Hindostan, where they are denominated "pandoo koolies," and are attributed to a fabulous being named Pandoo and his sons. With a similarity of character attesting their common origin, we find them in India, on the shores of the Levant and Mediterranean, in Belgium, Denmark, Sweden and Norway, in France, and on the shores of Britain from the Straits of Dover to the Land's End in Cornwall, as well as in many of the interior parts of the country. They are classed as follows: — 1. The single stone, pillar, or obelisk. 2. Circles of stones of different number and arrangement. 3. Sacrificial stones. 4. Cromlechs and cairns. 5. Logan stones. 6. Tolmen or colossal stones.

13. (1.) *Single Stones.* — Passages abound in Scripture in which the practice of erecting single stones is recorded. The reader on this point may refer to *Gen.* xxviii. 18. *Judges*, ix. 6., 1 *Sam.* vii. 12., 2 *Sam.* xx. 8., *Joshua*, xxiv. 27. The single stone might be an emblem of the generative power of Nature, and thence an object of idolatry. That mentioned in the first scriptural reference, which Jacob set up in his journey to visit Laban his uncle, and which he had used for his pillow, seems, whether from the vision he had while sleeping upon it, or from some other cause, to have become to him an object of singular veneration; for he set it up, and poured oil upon it, and called it "Bethel" (the house of God). It is curious to observe that some pillars in Cornwall, assumed to have been erected by the Phœnicians, still retain the appellation *Bothel.* At first, these stones were of no larger dimension than a man could remove, as in the instance just cited, and that of the Gilgal of Joshua (*Josh.* iv. 20.); but that which was set up *under an oak* at Shechem was a great stone. And here we may notice another singular coincidence, that of the Bothel in Cornwall being set up in a place which, from its proximity to an oak which was near the spot, was called Bothel-ac; the last syllable being the Saxon for an oak. It appears from the Scriptures that these single stones were raised on various occasions; sometimes, as in the case of Jacob's Bethel and of Samuel's Ebenezer, to commemorate instances of divine interposition; sometimes to record a covenant, as in the case of Jacob and Laban (*Gen.* xxxi. 48.); sometimes, like the Greek stelæ, as sepulchral stones, as in the case of Rachel's grave (*Gen.* xxxvi. 20.), 1700 years B.C., according to the usual reckoning. They were occasionally, also, set up to the memory of individuals, as in the instance of Absalom's pillar and others. The pillars and altars of the patriarchs appear to have been erected in honour of the only true God, Jehovah; but wherever the Canaanites appeared, they seem to have been the objects of idolatrous worship, and to have been dedicated to Baal or the sun, or the other false deities whose altars Moses ordered the Israelites to destroy. The similarity of pillars of single stones almost at the opposite sides of the earth, leaves no doubt in our mind of their being the work of a people of one common origin widely scattered; and the hypotheses of Bryant and Higgins sufficiently account for their appearance in places so remote from each other. In consequence, says the latter writer, of some cause, no matter what, the Hive, after the dispersion, casted and sent forth its swarms. One of the largest descended, according to Genesis (x. 2.), from Gomer, went north, and then west, pressed by succeeding swarms, till it arrived at the shores of the Atlantic Ocean, and ultimately colonised Britain. Another branch, observes the same author, proceeded through Sarmatia southward to the Euxine (Cimmerian Bosphorus); another to Italy, founding the states of the Umbrii and the Cimmerii, at Cuma, near Naples. Till the time of the Romans these different lines of march, like so many sheepwalks, were without any walled cities. Some of the original tribe found their way into Greece, and between the Carpathian mountains and the Alps into Gaul, scattering a few stragglers as they passed into the beautiful valleys of the latter, where traces of them in Druidical monuments and language are occasionally found. Wherever they settled, if the conjecture is correct, they employed themselves in recovering the lost arts of their ancestors.

14. To the Canaanites of Tyre and Sidon may be chiefly attributed the introduction of these primeval works into Britain. The Tyrians, inhabiting a small slip of barren land, were essentially and necessarily a commercial people, and became the most expert and adventurous sailors of antiquity. It has been supposed that the constancy of the needle to the pole, "that path which no man knoweth, and which the vulture's eye hath not seen,"

was known to the Tyrians; and, indeed, it seems scarcely possible that, by the help of the stars alone, they should have been able to maintain a commerce for tin on the shores of Britain, whose western coast furnished that metal in abundance, and whose islands (the Scilly) were known by the title of Cassiterides, or tin islands. In this part of Britain there seems unquestionable evidence that they settled a colony, and were the architects of Stonehenge, Abury, and other similar works in the British islands. In these they might have been assisted by that part of the swarm which reached our shores through Gaul; or it is possible that the works in question may be those of the latter only, of whom traces exist in Britany at the monument of Carnac, whereof it is computed 4000 stones still remain. From among the number of pillars of this kind still to be seen in England, we give (*fig.* 3.) that standing at Rudstone, in the east riding of Yorkshire. It is described by Drake, in his *Eboracum*, as "coarse rag stone or millstone grit, and its weight is computed at between 40 and 50 tons. In form (the sides being slightly concave) it approaches to an ellipse on the plan, the breadth being 5 ft. 10 in., and the thickness 2 ft. 3 in., in its general dimensions. Its height is 24 ft.; and, according to a brief account communicated to the late Mr. Pegge, in the year 1769 (*Archæologia*, vol. v. p. 95.), its depth underground equals its height above, as appeared from an experiment made by the late Sir William Strickland."

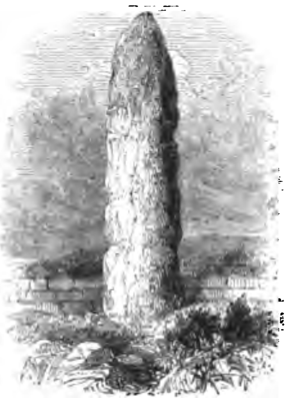


Fig. 3. PILLAR AT RUDSTONE.

15. (2.) *Circles of Stone.*—The Israelites were in the habit of arranging stones to represent the twelve tribes of Israel (*Exod.* xxiv. 4.), and for another purpose. (*Deut.* xxvii. 2.) And in a circular form we find them set up by Joshua's order on the passage of the Israelites through Jordan to Gilgal (גלגל); a word in which the radical Gal or Gil (signifying a wheel) is doubled to denote the continued repetition of the action. In this last case, Joshua made the arrangement a type of the Lord rolling away their reproach from them.

16. Though traces of this species of monument are found in various parts of the world, even in America, we shall confine our observations to those of Abury and Stonehenge, merely referring, by way of enumeration, to the places where they are to be found. Thus we mention Rolbrich in Oxfordshire, the Hurlers in Cornwall, Long Meg and her daughters in Cumberland, remains in Derbyshire, Devonshire, Dorsetshire, at Stanton Drew in Somersetshire, and in Westmoreland. They are common in Wales, and are found in the Western Isles. There are examples in Iceland, Norway, Sweden, Denmark, and various parts of Germany. Clarke, in his description of the hill of Kushunlu Tepe in the Troad, observes, that all the way up, the traces of former works may be noticed, and that, on the summit, there is a small oblong area, six yards long and two broad, exhibiting vestiges of the highest antiquity; the stones forming the inclosure being as rude as those of Tiryns in Argolis, and encircled by a grove of oaks covering the top of this conical mountain. The entrance is from the south. Upon the east and west, outside of the trees, are stones ranging like what we in England call Druidical circles. Three circles of stones are known in America, one of which stands upon a high rock on the banks of the river Winnipigon. The stupendous monument of Carnac in Britany, of which we have above made mention, is not of a circular form; the stones there being arranged in eleven straight lines, from 30 to 33 ft. apart, some of which are of enormous size. They are said to have formerly extended three leagues along the coast. A description of this monument is given in vol. xxii. of the *Archæologia*.

17. Abury, or Avebury, in Wiltshire, of which we give a view in a restored state (*fig.* 4.), is a specimen of this species of building, in which the climax of magnificence was attained. Stukely, who examined the ruins when in much better preservation than at present, says, "that the whole figure represented a snake transmitted through a circle;" and that, "to make their representation more natural, they artfully carried it over a variety of elevations and depressions, which, with the curvature of the avenues, produces sufficiently the desired effect. To make it still more elegant and picture-like, the head of the snake is carried up the southern promontory of Hackpen Hill, towards the village of West Kennet; nay, the very name of the hill is derived from this circumstance;" for *acan*, he observes, signifies a serpent in the Chaldaic language. Dr. S. then goes on to state, "that the *dracontia* was a name, amongst the first-learned nations, for the very ancient sort of temples of which they could give no account, nor well explain their meaning upon it." The figure of the serpent extended two miles in length; and but a very faint idea can now be formed of what it was in its original state. Two double circles, one to the north and the other to the south of the centre, were placed within the large circle, which formed the principal body of the serpent, and from which branched out the head to Hackpen Hill, in the direction of

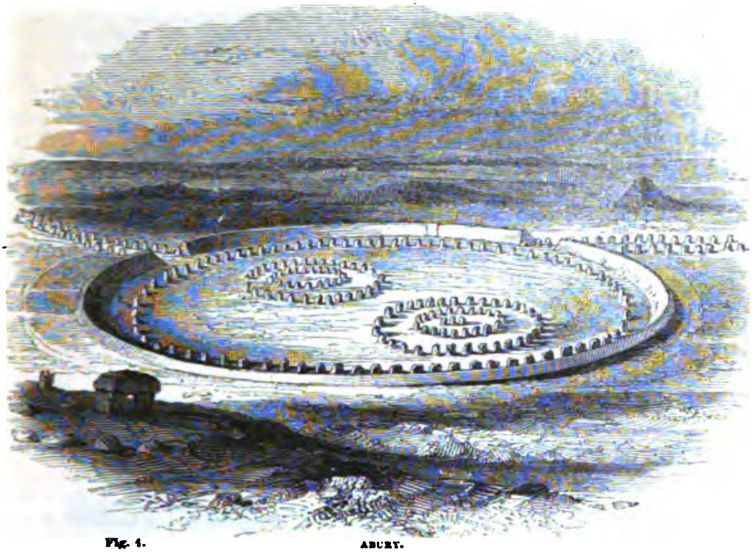


Fig. 4. ABURY.

West Kennet, as one avenue; and the other, the tail, in the direction of Beckhampton. Dr. Stukely makes the number of stones, 652 in all, as under: —

	Stones.		Stones.
The great circle	100	Beckhampton avenue	200
Outer circle north of the centre	30	Outer circle of Hackpen	40
Inner ditto	12	Inner ditto	18
Outer circle, south	30	Long stone. Cove jambs	2
Inner ditto	12	A stone he calls the ring stone	1
Cove and altar stone, north circle	4	Closing stone of the tail	1
Central pillar and altar, south circle	2		
Kennet avenue	200	Total	652

Of these, only seventy-six stones remained in the Kennet avenue in 1722. The large circle was enclosed by a trench or vallum upwards of 50 ft. in depth and between 60 and 70 ft. in width, leaving entrances open where the avenues intersected it. The colossal mound, called "Silbury hill," close to the Bath road, was probably connected in some way with the circle we have described, from the circumstance of the Roman road to Bath, made long afterwards, being diverted to avoid it. Dr. Owen thinks that the Abury circle was one of three primary circles in Great Britain, and that Silbury hill was the pile of Cyvrangon (heaping) characterised in the 14th Welsh triad; but the conjecture affords us no assistance in determining the people by whom the monument was raised. If it be in its arrangement intended to represent a serpent, it becomes immediately connected with ophiolatry, or serpent worship, a sin which beset the Israelites, and which would stamp it as proceeding from the central stamen of the hypothesis on which Mr. Higgins sets out.

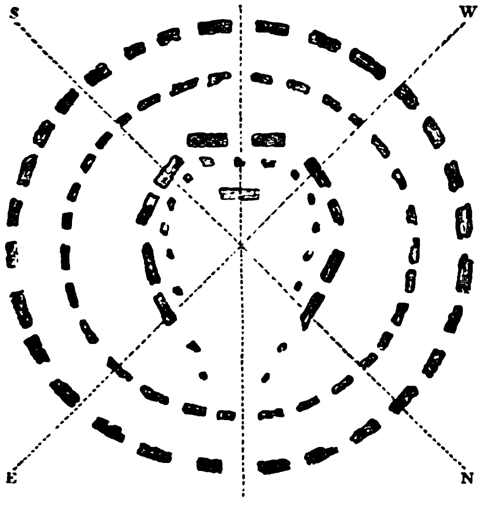


Fig. 5. PLAN OF STONEHENGE.

18. Stonehenge, on Salisbury Plain, about seven miles from Salisbury and two miles to the west of Ambresbury, is certainly more artificial in its structure than Abury, and its construction may therefore be

safely referred to a later date. *Fig. 5.* is a restored plan of this wonder of the west, as it may well be called. The larger circle is 105 feet in diameter, and between it and the interior smaller circle is a space of about 9 feet. Within this smaller circle, which is half the height (8 feet) of the exterior one, was a portion of an ellipsis formed by 5 groups of stones, to which Dr. Stukely has given the name of trilithons, because formed by two vertical and one horizontal stone: the former are from 17 to 18½ feet high, the middle trilithon being the highest. Within this ellipsis is another of single stones, half the height of the trilithons. The outer circle was crowned with a course of stones similar to an architrave or epissylium, the stones whereof were let into or joggled with one another by means of egg-shaped tenons formed out of the vertical blocks. The ellipsis was connected in a similar manner. Within the inner elliptical enclosure was a block 16 ft. long, 4 ft. broad, and 20 in. thick. This has usually been called the altar stone. Round the larger circle, at the distance of 100 ft., a vallum was formed about 52 ft. in width, so that the external dimension of the work was a diameter of 420 ft. The vallum surrounding these sacred places seems to have been borrowed by the Canaanites in imitation of the enclosure with which Moses surrounded Mount Sinai, in order to prevent the multitude from approaching too near the sacred mysteries. The number of stones composing this monument is variously given. In the subjoined account we follow Dr. Stukely: —

	Stones.		Stones.
Great circle, vertical stones	30	Stones within vallum	2
Epistylia	30	A large table stone	1
Inner circle	40	Distant pillar	1
Vertical stones of outer ellipsis	10	Another stone, supposed to have been opposite the entrance	1
Epistylia to them	5		
Inner ellipsis	19		
Altar	1	Total	140

Northwards from Stonehenge, at the distance of a few hundred yards, is a large single stone, which, at the period of its being placed there, has been by some thought to have marked a meridian line from the centre of the circle.

19. *Fig. 6.* is a view of the present state of this interesting ruin from the west. Mr. Cunnington, in a letter to Mr. Higgins, gives the following account of the stones which remain of the monument: — "The stones on the outside of the work, those comprising the outward circle as well as the large (five) trilithons, are all of that species of stone called '*garsen*' found in the neighbourhood; whereas the inner circle of small upright stones, and those of the interior oval, are composed of granite, hornstone, &c., most probably procured from some part of Devonshire or Cornwall, as I know not where such stones could be procured at a nearer distance."

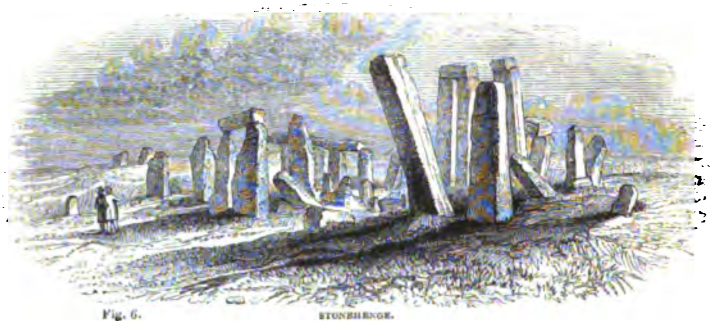


Fig. 6. STONEHENGE.

20. Authors have in Stonehenge discovered an instrument of astronomy, and among them Maurice, whose view as to its founders coincides with those of the writers already cited, and with our own. We give no opinion on this point, but shall conclude the section by placing before the reader the substance of M. Bailly's notion thereon, recommending him to consult, in that respect, authorities better than we profess to be, and here expressing our own belief that the priests of ancient Britain were priests of Baal; and that the monuments, the subjects of this section, were in existence long before the Greeks, as a nation, were known, albeit they did derive the word Druid from δρυς (an oak), and said that they themselves were αυτοχθονες (sprung from the earth).

21. M. Bailly says, on the origin of the sciences in Asia, that a nation possessed of profound wisdom, of elevated genius, and of an antiquity far superior to the Egyptians or Indians, immediately after the flood inhabited the country to the north of India, between the latitudes of 40° and 50°, or about 50° north. He contends that some of the most celebrated observatories and inventions relating to astronomy, from their peculiar character, could have taken place only in those latitudes, and that arts and improvements gradually

travelled thence to the equator. The people to whom his description is most applicable is the northern progeny of Brahmins, settled near the Imaus and in Northern Thibet. We add, that Mr. Hastings informed Maurice of an immemorial tradition that prevailed at Benares, which was itself, in modern times, the grand emporium of Indian learning, — that all that of India came from a country situate in 40° of N. latitude. On this Maurice says, " This is the latitude of Samarcand, the metropolis of Tartary; and, by this circumstance, the position of M. Bailly should seem to be confirmed. This is the country where, according to the testimony of Josephus and other historians cited by the learned Abbé Pezron, are to be found the first Celtæ, by whom all the temples and caves of India were made. Higgins observes on this, that the worship of the Mithraitic bull existed in India, Persia, Greece, Italy, and Britain, and that the religion of the Druids, Magi, and Brahmins was the same.

22. (3.) *Sacrificial Stones.* — These have been confounded with the cromlech, but the difference between them is wide. They are simple stones, either encircled by a shallow trench (vallum) and bank (agger), or by a few stones. Upon these almost all authors concur in believing that human immolation was practised; indeed, the name blod, or blood-stones, which they bear in the north of Europe, seems to point to their infernal use. We do not think it necessary to pursue further inquiry into them, as they present no remarkable nor interesting features.

23. (4.) *Cromlechs and Cairns.* — The former of these seem to stand in the same relation to the large circles that the modern cell does to the conventual church of the Catholics. They consist of two or more sides, or vertical stones, and sometimes a back stone, the whole being covered with one not usually placed exactly horizontal, but rather in an inclining position. We here (*fig.* 7.) give a representation of one, that has received the name of Kit's Cotty House, which lies on the road between Maidstone and Rochester, about a mile north-eastward from Aylesford church, and is thus described in the *Beauties of England and Wales.* It " is composed of four huge stones unwrought, three of them standing on end but inclined inwards, and supporting the fourth, which lies transversely over them, so as to leave an open recess beneath. The dimensions and computed weights of these stones are as follows: — height of that on the south side 8 ft., breadth 7½ ft., thickness 2 ft., weight 8 tons; height of that on the north side 7 ft., breadth 7½ ft., thickness 2 ft., weight 8½ tons. The middle stone is very irregular; its medium length as well as breadth may be about 5 ft., its thickness about 1 ft. 2 in., and its weight about 2 tons. The upper stone or impost is also extremely irregular; its greatest length is nearly 12 ft., and its breadth about 9¼ ft.; its thickness is 2 ft., and its weight about 10½ tons: the width of the recess at bottom is 9 ft., and at top 7½ ft.; from the ground to the upper side of the covering stone is 9 ft. These stones are of the kind called Kentish rag. Many years ago there was a single stone of a similar kind and size to those forming the cromlech, about 70 yards to the north-west: this, which is thought to have once stood upright, like a pillar, has been broken into pieces and carried away." Another cromlech stood in the neighbourhood, which has been thrown down. The nonsense that has been gravely written upon this and similar monuments is scarcely worth mention. It will hardly be believed that there existed people who thought it was the sepulchral monument of king Catigern, from similarity of name, and others who consider it the grave of the Saxon chief, Horsa, from its proximity to Horsted. Cromlechs are found in situations remote indeed, a specimen being seated on the Malabar coast; and in the British isles they are so numerous, that we do not think it necessary to give a list of them.

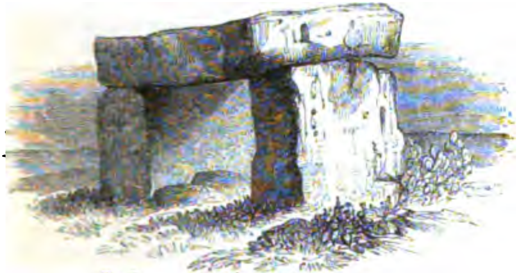


Fig. 7 KIT'S COTTY HOUSE.

24. The *cairn* or *carn* which we have in this section coupled with the cromlech, perhaps improperly, is a conical heap of loose stones. Whether its etymology be that of Rowland, from the words קרן־נד (kern-ned), a coped heap, we shall, from too little skill in Hebrew, not venture to decide; so we do not feel quite sure that, as has been asserted, they were raised over the bodies of deceased heroes and chieftains. Our notion rather inclines to their having been a species of altar, though the heap of stones to which Jacob gave the name of Galeed, if it were of this species, was rather a memorial of the agreement between him and Laban. It can scarcely be called an architectural work; but we should have considered our notice of the earlier monuments of antiquity incomplete without naming the cairn.

25. (5.) *Logan or Rocking Stones.* — These were large blocks poised so nicely on the points of rocks, that a small force applied to them produced oscillation. The weight of the celebrated one in Cornwall, which is granite, has been computed at upwards of 90 tons.

The use of these stones has been conjectured to be that of testing the innocence of persons accused of crime, the rocking of the stone being certain, unless wedged up by the judge of the tribunal, in cases where he knew the guilt of the criminal: but we think that such a purpose is highly improbable.

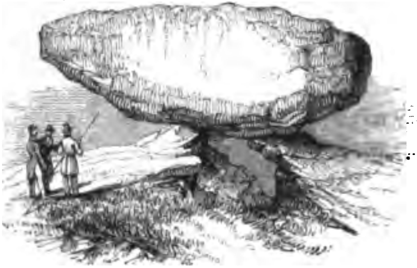


Fig. 8. TOLMEN IN CORNWALL.

26. (6.) *Tolmen or Colossal Stones.* — The Tolmen, or hole of stone, is a stone of considerable magnitude, so disposed upon rocks as to leave an opening between them, through which an object could be passed. It is the general opinion in Cornwall that invalids were cured of their diseases by being passed through the opening above mentioned. "The most stupendous monument of this kind," (see *fig.* 8.) says Borlase, "is in the tenement of Mên, in the parish of Constantine, in Cornwall; it is one great oval pebble, placed on the points of two natural rocks, so that a man may creep under the great one, between the supporters, through a passage of about three feet wide, by as much high. The longest diameter of this stone is 33 ft., being in a direction due north and south. Its height, measured perpendicularly over the opening is, 14 ft. 6 in., and the breadth, in the widest part, 18 ft. 6 in., extending from east to west. I measured one half of the circumference, and found it, according to my computation, 48½ ft., so that this stone is 97 ft. in circumference, lengthwise, and about 60 ft. in girt, measured at the middle; and, by the best information, it contains about 750 tons." We close this section by the expression of our belief that the extraordinary monuments whereof we have been speaking are of an age as remote as, if not more so than, the pyramids of Egypt, and that they were the works of a colony of the great nation that was at the earliest period settled in central Asia, either through the swarm that passed north-west over Germany, or south-west through Phœnicia; for, on either route, but rather, perhaps, the latter, traces of gigantic works remain, to attest the wonderful powers of the people of whom they are the remains.

Sect. II.

PELASGIC OR CYCLOPEAN ARCHITECTURE.

27. Pelasgic or Cyclopean architecture, (for that as well as the architecture of Phœnicia, seems to have been the work of branches of an original similarly thinking nation) presents for the notice of the reader, little more than massive walls composed of huge pieces of rock, scarcely more than piled together without the connecting medium of cement of any species. The method of its construction, considered as masonry, to the eye of the architect is quite sufficient to connect it with what we have in the preceding section called Druidical or Celtic architecture. It is next to impossible to believe that all these species were not executed by the same people. The nature and principles of Egyptian art were the same, but the specimens of it which remain bear marks of being of later date, the pyramids only excepted. The Greek fables about the Cyclopeans have been sufficiently exposed by Jacob Bryant, who has shown that the Greeks knew nothing about their own early history. Herodotus (lib. v. cap. 6.) alludes to them under the name of Cadmians, saying they were particularly famous for their architecture, which he says they introduced into Greece; and wherever they came, erected noble structures remarkable for their height and beauty. These were dedicated to the Sun under the names of Elorus and Pelorus. Hence every thing great and stupendous was called Pelorian; and, transferring the ideas of the works to the founders, they made them a race of giants. Homer says of Polyphemus, —

Και γαρ θαυμ' ετετυκτο πελωριον, ουδε εῳκει
Ανδρι γε σιτοφαγῳ, αλλα ῥιῳ ὑληεντι.

Virgil, too, describes him "Ipse arduus, alta pulsat sidera." Famous as lighthouse builders, wherein a round casement in the upper story afforded light to the mariner, the Greeks turned this into a single eye in the forehead of the race, and thus made them a set of monsters. Of the race were Trophonius and his brother Agamedes, who, according to Pausanias (lib. ix.) contrived the temple at Delphi and the Treasury constructed to Urius. So great was the fame for building of the Cyclopeans that, when the Sybil in Virgil shows Æneas the place of torment in the shades below, the poet separates it from the regions of bliss by a Cyclopean wall: —

"—— Cyclopum educta caminis
Mœnia conspicio." *Æn.* lib. vi. v. 630.

28. The walls of the city of Mycene are of the class denominated Cyclopean, thus denounced for ruin by Hercules in Seneca: —

> " —— Quid moror? majus mihi
> Bellum Mycenis restat, ut Cyclopea
> Eversa manibus mœnia nostris concidant." *Hercules Furens*, act. 4. v. 996.

29. The gate of the city and the chief tower were particularly ascribed to them (Pausanias, lib. ii.) Argos had also the reputation of being Cyclopean. But, to return to Mycene, Euripides, we should observe, speaks of its walls as being built after the Phœnician rule and method: —

> —— Ως τα Κυκλωπων βαθρα
> Φοινικι κανονι και τυκοις ἡρμοσμενα. *Hercules Furens*, v. 944.

30. *Fig.* 9. is a representation of a portion of the postern gate of the walls of Mycene, for the purpose of exhibiting to the reader the character of the masonry employed in it.

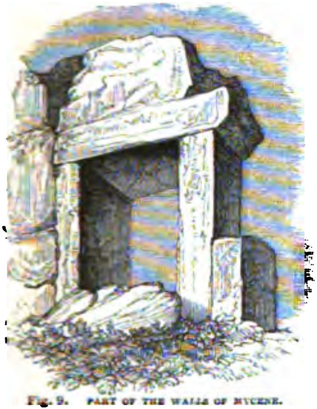


Fig. 9. PART OF THE WALLS OF MYCENE.

31. The walls of Tiryns, probably more ancient than those we have just named, are celebrated by Homer in the words Τιρυνθα τειχιοεσσαν, and are said by Apollodorus and Strabo to have been built by workmen whom Prætus brought from Lycia. The words of Strabo are, Τιρυνθι ὁρμητηριῳ χρησασθαι δοκει Προιτος, και τειχισαι δια Κυκλωπων· οὓς ἑπτα μεν ειναι, καλεισθαι δε Γαστεροχειρας, τρεφομενους εκ της τεχνης, *Prœtus appears to have used Tiryns as a harbour, and to have walled it by the assistance of the Cyclops, who were seven in number, and called Gastrocheirs* (belly-handed), *living by their labour.* " These seven Cyclops," says Jacob Bryant, " were, I make no doubt, seven Cyclopean towers built by the people." Further on, he adds, " These towers were erected likewise for Purait, or Puratheia, where the rites of fire were performed: but Purait, or Puraitus, the Greeks changed to Prætus; and gave out that the towers were built for Prætus, whom they made a king of that country." The same author says that the Cyclopeans worshipped the sun under the symbol of a serpent; thus again connecting them with the builders of Abury noticed in page 6. *Fig.* 10. is a view of some portions of the walls of Tiryns, and for others we refer the reader to the *Travels in Albania*, by the Rev. Mr. Hughes.

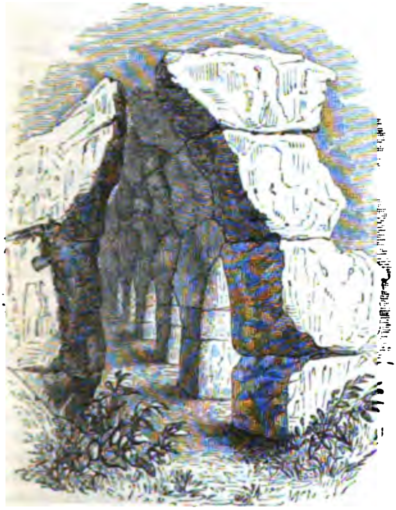


Fig. 10. PART OF THE WALLS OF TIRYNS.

32. Mr. Hamilton (*Archæologia*) divides the specimens of Cyclopean buildings into four æras. In the first he includes Tiryns and Mycene, where the blocks composing the masonry are of various sizes, having or having had smaller stones in their interstices. Second, as at Julis and Delphi, masonry without courses, formed of irregular polygonal stones, whose sides fit to each other. Third, that in which the stones are laid in courses of the same height, but unequal in length of stones; of this species are specimens in Bœotia, Argolis, and the Phocian cities. Fourth and last, that in which the stones are of various heights, and always rectangular, whereof examples are found in Attica. It must here be observed that, in the Etrurian part of Italy, Cyclopean works exist, particularly of those which Mr. Hamilton places in the second æra; as at Norba in Latium, Cora, Signia, and Alatrium; in the three last whereof the walls resemble those of Tiryns, Argos, and Mycene; and at Fiesole, Arezzo, and other places.

33. We shall now return to some further particulars in relation to Tiryns and Mycene, from which a more distinct notion of these fortresses will be obtained; but further investigation of those in Italy will hereafter be necessary, under the section on Etruscan architecture. The Acropolis of Tiryns, a little to the south-east of Argos, is on a mount rising about fifty

feet above the level of the plain, the foundations of its inclosure being still perfect and traceable, as in the annexed figure (*fig.* 11.). The ancient city is thought to have surrounded the fortress, and that formerly the city was nearer the sea than at present. Bryant, with his usual ingenuity, has found in its general form a type of the long ship of Danaus, which, we confess, our imagination is not lively enough to detect. On the east of the fortress are quarries, which furnish stone similar to that whereof it is built. It had entrances from the east and the west, and one at the south-eastern angle. That on the east, lettered A, is pretty fairly preserved, and is approached by an inclined access, B, 15 ft. wide, along the eastern and southern sides of the tower, C, which is 20 ft. square and 40 ft. high, passing, at the end of the last named side, under a gateway, composed of very large blocks of stone, that which forms the architrave being 10 ft. long, and over which, from the fragments lying on the spot, it is conjectured that a triangular stone was placed; but thereon is no appearance of sculpture. D is the present entrance. The general thickness of the walls is 25 ft., and they are formed by three parallel ranks of stones 5 ft. thick, thus leaving two ranges of galleries each 5 ft. wide and 12 ft. high. The sides of the galleries are formed by two courses of stone, and the roof by two other horizontal courses, sailing over so as to meet at their summit, and somewhat resembling a pointed arch. See *fig.* 11. That part of the gallery, *fig.* 12., now uncovered, is about 90 ft. long, and has six openings or recesses towards the east, one whereof seems to have afforded a communication with some exterior building, of whose foundation traces are still in existence. The interval between these openings varies from 10 ft. 6 in. to 9 ft. 8 in.; the openings themselves being from 5 ft. 6 in. to 4 ft. 10 in. wide. It is probable that these galleries extended all round the citadel, though now only accessible where the walls are least perfect, at the southern part of the inclosure. There are no remains of the south-eastern portal. It appears to have been connected with the eastern gate by an avenue enclosed between the outer and inner curtain, of which avenue the use is not known. Similar avenues have been found at Argos and other ancient cities in Greece. The northern point of the hill is least elevated, and smaller stones have been employed in its wall. The exterior walls are built of rough stones, some of which are 9 ft. 4 in. in length and 4 ft. thick, their common size being somewhat less When entire, the wall must have been 60 ft. high, and on the eastern side has been entirely destroyed. The whole length of the citadel is about 660 ft., and the breadth about 180 ft., the walls being straight without regard to inequality of level in the rock.

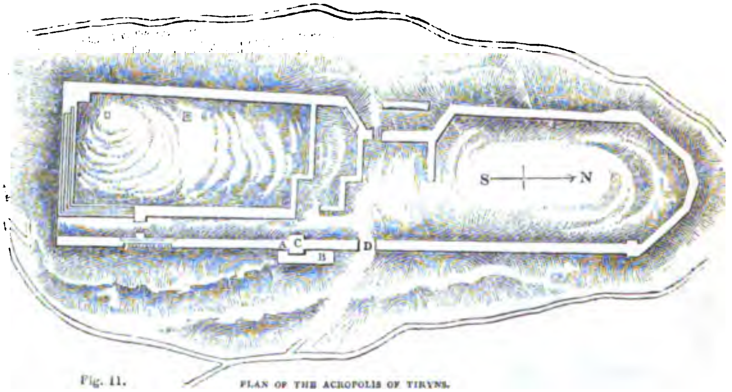


Fig. 11. PLAN OF THE ACROPOLIS OF TIRYNS.

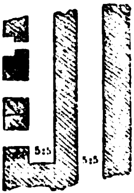


Fig. 12. GALLERY.

34. The Acropolis of Mycene was probably constructed in an age nearly the same as that of Tiryns. Pausanias mentions a gate on which two lions were sculptured, to which the name of the Gate of the Lions has been given (*fig.* 13.) These are still in their original position. It is situate at the end of a recess about 50 ft. long, commanded by projections of the walls, which are here formed of huge blocks of square stones, many placed on each other without breaking joint, which circumstance gives it a very inartificial appearance. The epistylium of the gate is a single stone 15 ft. long and 4 ft. 4 in. high. To the south of the gate above mentioned the wall is much ruined. In one part something like a tower is discernible, whose walls, being perpendicular while the curtain inclines a little inward from its base, a projection remained at the top by which an archer could defend the wall below. The blocks of the superstructure are of great size, those of the substructure much smaller. The gates excepted, the whole citadel is built of rough masses of rock, nicely adjusted and fitted to each other, though the smaller stones with which the

interstices were filled have mostly disappeared. The southern ramparts of the citadel and all the other walls follow the natural irregularity of the precipice on which they stand. At its eastern point it is attached by a narrow isthmus to the mountain. It is a long irregular triangle, standing nearly east and west. The walls are mostly of well-jointed polygonal stones, although the rough construction occasionally appears. The general thickness of the walls is 21 ft., in some places 25; their present height, in the most perfect part, is 43 ft. There are, in some places, very slight projections from the walls, resembling towers, whereof the most perfect one is at the south-east angle, its breadth being 33 ft. and its height 43 ft. The size of the block whereon the lions are sculptured is 11 ft. broad at the base, 9 ft. high, and about 2 ft. thick, of a triangular form suited to the recess made for its reception. This block, in its appearance, resembles the green basalt of Egypt.

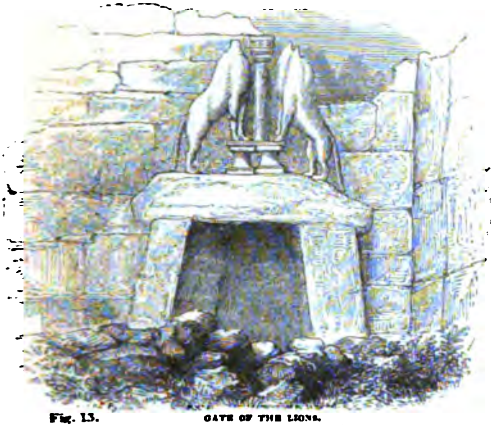


Fig. 13. GATE OF THE LIONS.

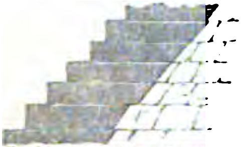


Fig. 14. TREASURY OF ATREUS.

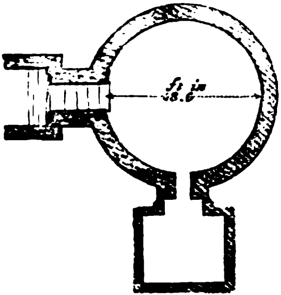


Fig. 15. PLAN OF TREASURY OF ATREUS.

35. In this place we think it proper to notice a building at Mycene, which has been called by some the Treasury of Atreus, or the tomb of his son Agamemnon mentioned by Pausanias. This building at first misled some authors into a belief that the use of the arch was known in Greece at a very early period; but examination of it shows that it was formed by horizontal courses, projecting beyond each other as they rose, and not by radiating joints or beds, and that the surface was afterwards formed so as to give the whole the appearance of a pointed dome, by cutting away the lower angles (*fig.* 14.). It is probably the most ancient of buildings in Greece; and it is a curious circumstance that at New Grange, near Drogheda, in Ireland, there is a monument whose form, construction, and plan of access resemble it so strongly that it is impossible to consider their similarity the result of accident. A representation of this may be seen in the work by Mr. Higgins which we have so often quoted, and will, we think, satisfy the reader of the great probability of the hypothesis hereinbefore assumed having all the appearance of truth. By the subjoined plan (*fig.* 15.) it will be seen that a space 20 ft. wide, between the two walls, conducts us to the entrance, which is 9 ft. 6 in. at the base, 7 ft. 10 in. at the top, and about 19 ft. high. The entrance passage is 18 ft. long and leads to the main chamber, which, in its general form, has some resemblance to a bee-hive, whose diameter is about 48 ft. and height about 49. (*fig.* 16.) The blocks are placed in courses as above shown, 34 courses being at present visible. They are laid with the greatest precision, without cement, and are unequal in size. Their average height may be taken at 2 ft., though to a spectator on the floor, from the effect of the perspective, they appear to diminish very much towards the vertex. This monument has a second chamber, to which you enter on the right from the larger one just described. This is about 27 ft. by 20, and 19 ft. high; but its walls, from the obstruction of the earth, are not visible. The doorway to it is 9½ ft. high, 4 ft. 7 in. wide at the base, and 4 ft. 3 in. at the top. Similar to the larger or principal doorway, it has a triangular opening over its lintel. The stones which fitted into these triangular openings were of enormous dimensions, for the height of that over the principal entrance is 12 ft., and its breadth 7 ft. 8 in. The vault has been either lined with metal or ornamented with some sort of decorations, inasmuch as a number of bronze nails are found fixed in the stones up to the summit. The lintel of the door consists of two pieces of stone, the largest whereof is 27 ft. long, 17 ft. wide, and 3 ft. 9 in. thick, calculated, therefore, at 133 tons weight; a mass which can be compared with none ever used in building, except those at Balbec and in Egypt. The other lintel is of the same height, and probably (its ends are hidden) of

the same length as the first. Its breadth, however, is only one foot Its exterior has two parallel mouldings, which are continued down the jambs of the doorway.

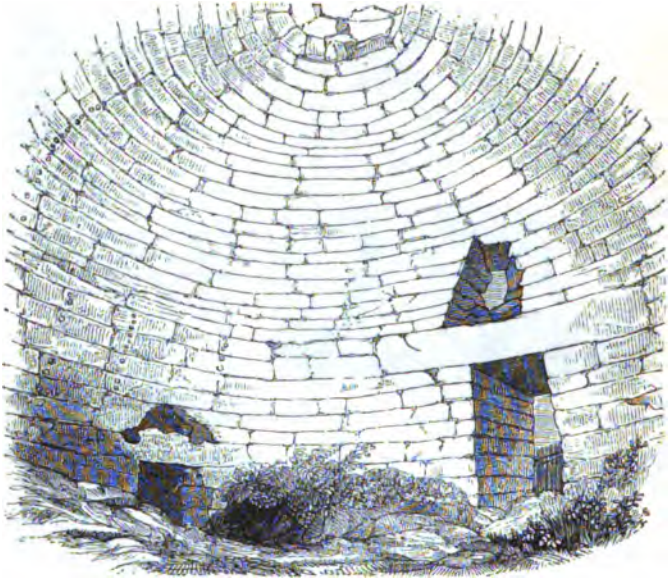


Fig. 16. CHAMBER OF TREASURY OF ATREUS.

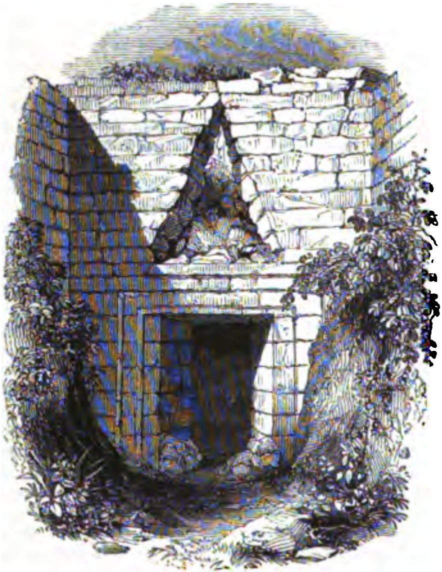


Fig. 17. TREASURY OF MINYAS.

36. The stone employed is of the hard and beautiful breccia, of which the neighbouring rocks, and the contiguous Mount Eubora, consist. It is the hardest and compactest breccia which Greece produces, resembling the antique marble called Breccia Tracagnina antica, sometimes found among the ruins of Rome. Near the gate lie some masses of rosso antico decorated with guilloche-like and zigzag ornaments, and a columnar base of a Persian character. Some have supposed that these belonged to the decorations of the doorway; but we are of a different opinion, inasmuch as they destroy its grand character. We think if this were the tomb of Agamemnon, they were much more likely to have been a part of the shrine in which the body or ashes were deposited.

37. It is conjectured that the treasury of Minyas king of Orchomenus, whereof Pausanias speaks, bore a resemblance to the building we have just described; and it is very probable that all the subterranean chambers of Greece, Italy, and Sicily were very similarly constructed. *Fig.* 17. represents the entrance to the building from the outside. As the architecture of the early races whereof we have been speaking will be further discussed in investigating other monuments, we do not think it necessary to enlarge further in this place on what we have termed Pelasgic or Cyclopean architecture.

Sect. III.

BABYLONIAN ARCHITECTURE.

38. The name prefixed to this section must not induce the reader to suppose we shall be able to afford him much instruction on this interesting subject. The materials are scanty; the monuments, though once stupendous, still more so. "If ever," says Keith, in his *Evidence of the Truth of the Christian Religion*, "there was a city that seemed to bid defiance to any predictions of its fall, that city was Babylon. It was for a long time the most famous city in the Old World. Its walls, which were reckoned among the wonders of the world, appeared rather like the bulwarks of nature than the workmanship of man." The city of Babylon is thus described by ancient writers. It was situated in a plain of vast extent, and divided into two parts by the river Euphrates, which was of considerable width at the spot. The two divisions of the city were connected by a massive bridge of masonry strongly connected with iron and lead; and the embankments to prevent inroads of the river were formed of the same durable materials as the walls of the city. Herodotus says that the city itself was a perfect square enclosed by a wall 480 furlongs in circumference, which would make it eight times the size of London. It is said to have had numbers of houses three or four stories in height, and to have been regularly divided into streets running parallel with each other, and cross ones opening to the river. It was surrounded by a wide and deep trench, from the earth whereof, when excavated, square bricks were formed and baked in a furnace. With these, cemented together through the medium of heated bitumen intermixed with reeds to bind together the viscid mass, the sides of the trenches were lined, and with the same materials the vast walls above mentioned were constructed. At certain intervals watch-towers were placed, and the city was entered by 100 gates of brass. In the centre of each of the principal divisions of the city a stupendous public monument was erected. In one (Major Rennel thinks that on the eastern side) stood the temple of Belus; in the other, within a large strongly fortified enclosure, the royal palace. The former was a square pile, each side being two furlongs in extent. The tower erected on its centre was a furlong in breadth and the same in height, thus making it higher than the largest of the pyramids, supposing the furlong to contain only 500 feet. On this tower as a base were raised, in regular succession, seven other lofty towers, and the whole, according to Diodorus, crowned with a bronze statue of the god Belus 40 feet high. See *fig.* 18., in which the dotted lines show the present remains, according to Sir R. K. Porter's account in his Travels. The palace, serving also as a temple, stood on an area 1½ mile square, and was surrounded by circular walls, which, according to Diodorus, were decorated with sculptured animals resembling life, painted in their natural colours, on the bricks of which they were depicted, and *afterwards burnt in*. Such was the city of Babylon in its meridian splendour, that city whose founder (if it were not Nimrod, sometimes called Belus,) is unknown. Great as it was, it was enlarged by Semiramis, and still further enlarged and fortified by Nebuchadnezzar. We shall now present, from the account of Mr. Rich, a gentleman who visited the spot near thirty years ago, a sketch of what the city now is. The first grand mass of ruins marked A (*fig.* 19.), which the above gentleman describes, he says extends 1100 yards in length and 800 in its greatest breadth, in figure nearly resembling a quadrant; its height is irregular, but the most elevated part may be about 50 or 60 ft. above the level of the plain, and it has been dug into for the purpose of procuring bricks. This mound Mr. R. distinguishes by the name of Amran. On the north is a valley 550 yards long, and then the second grand heap of ruins, whose shape is nearly a square of 700 yards long and broad; its south-west angle being connected with the north-west angle of the mounds of Amran by a high ridge nearly 100 yards in breadth. This is the place where Beauchamp made his observations, and is highly interesting from every vestige of it being composed of buildings far superior to those whereof there are traces in the eastern quarter. The bricks are of the finest description, and, notwithstanding this spot being the principal magazine of them and constantly used for a supply, are still in abundance. The operation of extracting the bricks has caused much confusion, and increased the difficulty of deciphering the use of this mound. In some places the solid mass has been bored into, and the superincumbent strata falling in, frequently bury workmen in the rubbish. In all these excavations walls of burnt brick laid in lime mortar of a good quality are to be seen; and among the ruins are to be found fragments of alabaster vessels, fine earthenware, marble, and great quantities of varnished tiles, whose glazing and colouring are surprisingly fresh. "In a

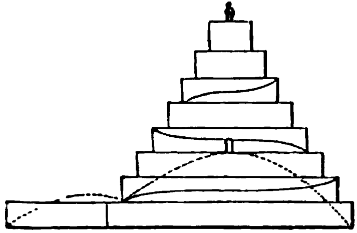


Fig. 18. TEMPLE OF BELUS.

hollow," observes Mr. Rich, "near the southern part, I found a sepulchral urn of earthenware, which had been broken in digging, and near it lay some human bones, which pulverised with the touch." Not more than 200 yards from the northern extremity of this mound, is a ravine near 100 yards long, hollowed out by those who dig for bricks, on one of whose sides a few yards of wall remain, the face whereof is clear and perfect, and appears to have been the front of some building. The opposite side is so confused a mass of rubbish, that it looks as if the ravine had been worked through a solid building. Under the foundations at the southern end was discovered a subterranean passage floored and walled with large bricks in bitumen, and covered over with pieces of sandstone a yard thick and several yards long, on which the pressure is so great as to have pushed out the side walls. What was seen was near seven feet in height, its course being to the south. The upper part of the passage is cemented with bitumen, other parts of the ravine with mortar, and the bricks have all writing on them. At the northern end of the ravine an excavation was made, and a statue of a lion of colossal dimensions, standing on a pedestal of coarse granite and rude workmanship, was discovered. This was about the spot marked E on the plan. A little to the west of the ravine at B is a remarkable ruin called the Kasr or Palace, which, being uncovered, and partly detached from the rubbish, is visible from a considerable distance. It is "so surprisingly fresh," says the author, "that it was only after a minute inspection I was satisfied of its being in reality a Babylonian remain." It consists of several walls and piers, in some places ornamented with niches, and in others strengthened by pilasters of burnt brick in lime cement of great tenacity. The tops of the walls have been broken down, and they may have been much higher. Contiguous to this ruin is a heap of rubbish, whose sides are curiously streaked by the alternation of its materials, probably unburnt bricks, of which a small quantity were found in the neighbourhood, without however any reeds in their interstices. A little to the N. N. E. of it is the famous tree which the natives call Athelì. They say it existed in ancient Babylon, and was preserved by God that it might afford a convenient place to Ali for tying up his horse after the battle Hellah!" "It is an evergreen," says Mr. R., "something resembling the lignum vitæ, and of a kind, I believe, not common in this part of the country, though I am told there is a tree of the description at Bassora." The valley which separates the mounds just described from the river is white with nitre, and does not now appear to have had any buildings upon it except a small circular heap at D. The whole embankment is abrupt, and shivered by the action of the water. At the narrowest part E, cemented into the burnt brick wall, there were a number of urns filled with human bones which had not undergone the action of fire. From a considerable quantity of burnt bricks and other fragments of building in the water the river appears to have encroached here.

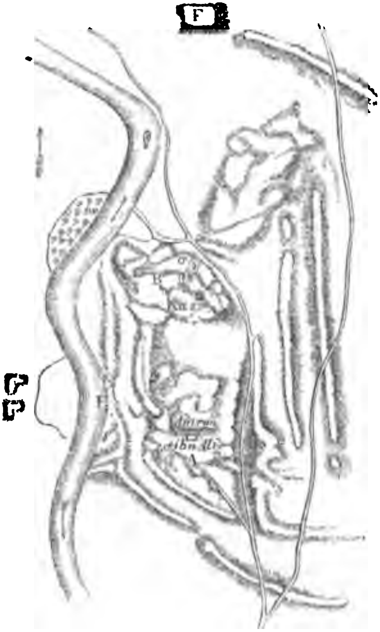


Fig. 19. PLAN OF BABYLON.

39. A mile to the north of the Kasr, and 950 yards from the bank of the river, is the last ruin of this series, which Pietro della Valle, in 1616, described as the tower of Belus, in which he is followed by Rennell. The natives call it, according to the vulgar Arab pronunciation of those parts, Mujelibè, which means overturned. They sometimes also apply the same term to the mounds of the Kasr. This is marked F on the plan. "It is of an oblong shape, irregular in its height and the measurement of its sides, which face the cardinal points, the northern side being 200 yards in length, the southern 219, the eastern 182, and the western 136. The elevation of the south-east or highest angle, 141 feet. The western face, which is the least elevated, is the most interesting on account of the appearance of building it presents. Near the summit of it appears a low wall, with interruptions, built of unburnt bricks mixed up with chopped straw or reeds and cemented with clay mortar of great thickness." The south-west angle seems to have had a turret, the others are less perfect. The ruin is much worn into furrows from the action of the weather, penetrating considerably into the mound in some places. The summit is covered with heaps of rubbish, among which fragments of burnt brick are found, and here and there

whole bricks with inscriptions on them. Interspersed are innumerable fragments of pottery, brick, bitumen, pebbles, vitrified brick or scoria, and even shells, bits of glass, and mother of pearl. The northern face of the Mujelibé (*fig.* 20.) contains a niche of the height of a man, at the back whereof a low aperture leads to a small cavity, whence a passage branches off to the right till it is lost in the rubbish. It is called by the natives the serdaub or cellar, and Mr. Rich was informed that four years previous to his survey, a quantity of marble was taken out from it, and a coffin of mulberry wood, in which was contained a human body enclosed in a tight wrapper, and apparently partially covered with bitumen, which crumbled into dust on exposure to the air. About this spot Mr. R. also excavated and found a coffin containing a skeleton in high preservation, whose antiquity was placed beyond dispute by the attachment of a brass bird to the outside of the coffin, and inside an ornament of the same material, which had seemingly been suspended to some part of the skeleton. On the western side of the river there is not the slightest vestige of ruins excepting opposite the mass of Amran, where there are two small mounds of earth in existence.

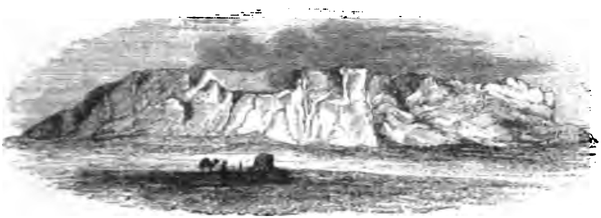


Fig. 20. NORTHERN FACE OF THE MUJELIBE.

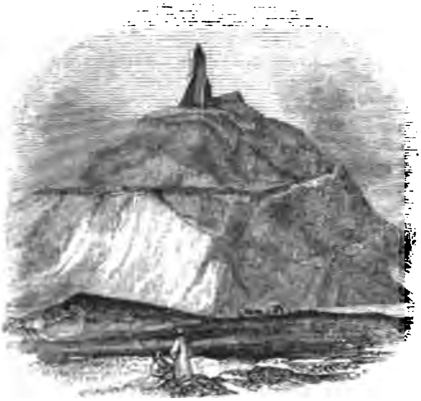


Fig. 21. BIRS NEMROUD.

40. The most stupendous and surprising mass of the ruins of ancient Babylon is situate in the desert, about six miles to the south-west of Hellah. It is too distant to be shown on the block plan above given. By the Arabs it is called Birs Nemroud; by the Jews, Nebuchadnezzar's Prison. Mr. Rich was the first traveller who gave any account of this ruin, of which *fig.* 21. is a representation; and the description following we shall present in Mr. Rich's own words. " The Birs Nemroud is a mound of an oblong figure, the total circumference of which is 762 yards. At the eastern side it is cloven by a deep furrow, and is not more than fifty or sixty feet high; but at the western it rises in a conical figure to the elevation of 198 ft., and on its summit is a solid pile of brick 37 ft. high by 28 in breadth, diminishing in thickness to the top, which is broken and irregular, and rent by a large fissure extending through a third of its height. It is perforated by small square holes disposed in rhomboids. The fine burnt bricks of which it is built have inscriptions on them; and so admirable is the cement, which appears to be lime mortar, that, though the layers are so close together that it is difficult to discern what substance is between them, it is nearly impossible to extract one of the bricks whole. The other parts of the summit of the hill are occupied by immense fragments of brickwork, of no determinate figure, tumbled together and converted into solid vitrified masses, as if they had undergone the action of the fiercest fire or been blown up with gunpowder, the layers of the bricks being perfectly discernible,—a curious fact, and one for which I am utterly incapable of accounting. These, incredible as it may seem, are actually the ruins spoken of by Pére Emanuel (See *D'Anville, sur l'Euphrate et le Tigre*), who takes no sort of notice of the prodigious mound on which they are elevated." The mound is a majestic ruin, and of a people whose powers were not lost, if the hypothesis brought before the reader in the previous section on Celtic and Druidical architecture be founded on the basis of truth, but shown afterwards, on their separation from the parent stock, in Abury, Stonehenge, Carnac, and many other places. Ruins to a considerable extent exist round the Birs Nemroud; but for our purpose it is not necessary to particularise them. The chance (for more the happiest conjecture would not warrant) of conclusively enabling the reader to come to a certain and definite notion of the venerable city, whereof it is our object to give him a faint idea, is far too indefinite to detain him and exhaust his patience. One circumstance, however, we must not omit; and again we shall use the words of the traveller to whom we are under so many obligations. They are, — " To these ruins I must add one, which, though not in the same direction, bears such strong characteristics of a Babylonian origin, that it would be

improper to omit a description of it in this place. I mean Akerkouf, or, as it is more generally called, Nimrod's Tower; for the inhabitants of these parts are as fond of attributing every vestige of antiquity to Nimrod as those of Egypt are to Pharaoh. It is situate ten miles to the north-west of Bagdad, and is a thick mass of unburnt brickwork, of an irregular shape, rising out of a base of rubbish; there is a layer of reeds between every fifth or sixth (for the number is not regulated) layer of bricks. It is perforated with small square holes, as the brickwork at the Birs Nemroud; and about half way up on the east side is an aperture like a window; the layers of cement are very thin, which, considering it is mere mud, is an extraordinary circumstance. The height of the whole is 126 ft.; diameter of the largest part, 100 ft.; circumference of the foot of the brickwork above the rubbish, 300 ft.; the remains of the tower contain 100,000 cubic feet. (Vide *Ives's Travels*, p. 298.) To the east of it is a dependent mound, resembling those at the Birs and Al Hheimar."

41. The inquiry (following Mr. Rich) now to be pursued is that of identifying some of the remains which have been described with the description which has been left of them. And, first, of the circuit of the city. The greatest circumference of the city, according to the authors of antiquity, was 480 stadia (supposed about 500 ft. each), the least 360. Strabo, who was on the spot when the walls were sufficiently perfect to judge of their extent, states their circuit at 385 stadia. It seems probable that within the walls there was a quantity of arable and pasture ground, to enable the population to resist a siege; and that, unlike modern cities, the buildings were distributed in groups over the area inclosed; for Xenophon reports that when Cyrus took Babylon (which event happened at night) the inhabitants of the opposite quarter of the town were not aware of it till the third part of the day; that is, three hours after sunrise. The accounts of the height of the walls all agree in the dimension of 50 cubits, which was their reduced height from 350 ft. by Darius Hystaspes, in order to render the town less defensible. The embankment of the river with walls, according to Diodorus 100 stadia in length, indicates very advanced engineering skill; but the most wonderful structure of the city was the tower, pyramid, or sepulchre of Belus, whose base, according to Strabo, was a stadium on each side. It stood in an enclosure of two miles and a half, and contained the temple in which divine honours were paid to the tutelary deity of Babylon. The main interest attached to the tower of Belus arises from a belief of its identity with the tower which we learn from Scripture (*Gen.* xi.) the descendants of Noah, with Belus at their head, constructed in the plains of Shinar. The two masses of ruins in which this tower must be sought, seem to be the Birs Nemroud, whose four sides are 2286 English feet in length; and the Mujelibé, whose circumference is 2111 ft. Now, taking the stadium at 500 ft., the tower of Belus, according to the accounts, would be 2000 ft. in circumference; so that both the ruins agree, as nearly as possible, in the requisite dimensions, considering our uncertainty respecting the exact length of the stadium. Mr. Rich evidently inclines to the opinion that the Birs Nemroud is the ruin of this celebrated temple, though he allows "a very strong objection may be brought against the Birs Nemroud in the distance of its position from the extensive remains on the eastern bank of the Euphrates, which for its accommodation would oblige us to extend the measurement of each side of the square to nine miles, or adopt a plan which would totally exclude the Mujelibé, all the ruins above it, and most of those below: even in the former case, the Mujelibé and the Birs would be at opposite extremities of the town close to the walls, while we have every reason to believe that the tower of Belus occupied a central situation."

42. The citadel or palace was surrounded by a wall whose total length was 60 stadia, within which was another of 40 stadia, whose inner face was ornamented with painting, — a practice (says Mr. Rich) among the Persians to this day. Within the last-named wall was a third, on which hunting subjects were painted. The old palace was on the opposite side of the river, the outer wall whereof was no larger than the inner wall of the new one. Above the palace or citadel were, according to Strabo, the hanging gardens, for which, in some respects, a site near the Mujelibé would sufficiently answer, were it not that the skeletons found there "embarrass almost any theory that may be formed on this extraordinary pile."

43. As yet, no traces have been found of the tunnel under the Euphrates, nor of the obelisk which Diodorus says was erected by Semiramis; it is not, however, impossible that the diligence and perseverance of future travellers may bring them to light. Rich believes that the number of buildings within the city bore no proportion to the extent of the walls, —a circumstance which has already been passingly noticed. He moreover thinks that the houses were, in general, small; and further, that the assertion of Herodotus, that it abounded in houses of two or three stories, argues that the majority consisted of only one. He well observes, "The peculiar climate of this district must have caused a similarity of habits and accommodation in all ages; and if, upon this principle, we take the present fashion of building as some example of the mode heretofore practised in Babylon, the houses that had more than one story must have consisted of the ground floor, or *basse-cour*, occupied by stables, magazines, and serdaubs or cellars, sunk a little below the ground, for

the comfort of the inhabitants during the heat; above this a gallery with the lodging rooms opening into it; and over all the flat terrace for the people to sleep on during the summer." In these observations we fully concur with the author, believing that climate and habits influence the arts of all nations.

44. Vastness of dimension, rather than refined art, may be reasonably inferred of the Babylonian architecture; the sculptures which have been seen are those of a people not so advanced in art as the Egyptians. From the similarity of the arrow-headed characters on the bricks found about the ruins of Babylon to those which appear on the ruins of Persepolis, we may fairly conjecture a similarity of habits and taste between the people of the two cities; of the latter we have more perfect remains than of the former, of which we shall furnish our readers with some examples in the next section. In Asia, about the provinces of which we have spoken, must be sought the first notions of the art. There its wonders first appeared; there it first developed its power. Greater almost at its birth than ever afterwards, it seems all at once to have risen, as respects absolute grandeur, to the highest state of which it was there susceptible; and, degenerating successively under the hands of other people, we may reckon by the periods of its decay the epochs of its duration.

45. No trace of the arch has been found in the ruins either at the Kasr or in the passages at the Mujelibé. Massy piers, buttresses, and pilasters supplied the place of the column. The timber they used was that of the date tree, posts of which were used in their domestic architecture, round which, says Strabo, they twist reeds and apply a coat of paint to them. Thickness of wall was obtained by casing rubble work with fine brick, of which two sorts were made. The one was merely dried in the sun, the other burned in a kiln. The latter was 13 in. square and 3 in. thick, with varieties for different situations in the walls. They are of various colours. The sun-dried is considerably larger than the kiln-dried. There is reason for believing that lime cement was more generally used than bitumen or clay; indeed, Niebuhr says that the bricks laid in bitumen were easily separated, but that where mortar had been employed no force could detach them from each other without breaking them in pieces.

SECT. IV.

PERSEPOLITAN AND PERSIAN ARCHITECTURE.

46. Persepolis, the ancient capital of Persia, whereof the few ruins now remaining we are about to describe, was seated (lat. 30° 40′ N., long. 84° E.) in the great plain of Merdasht or Istakhr, one of the most fertile in the world, being watered in all directions by rivulets and artificial drains, which ultimately unite in the Bundemir, the ancient Araxes. The site of this city, destroyed two thousand years since, would, like Memphis, have scarcely left a vestige by which it could have been identified, but for the celebrated ruins of Chel-Minar (*fig.* 22.), which are believed to be the remains of that ancient palace of the masters of Asia to which Alexander set fire in a moment of madness and debauch. The information we are about to give on this subject is obtained from De Bruyn, who examined the ruins with great attention in 1704, with some reference also to Niebuhr and Sir R. K. Porter, the latest traveller who has published any account of them.

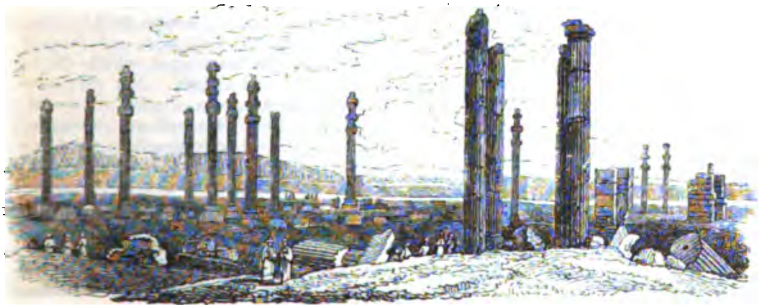


Fig. 22. RUINS OF PERSEPOLIS.

47. The ruins are situated at the foot and to the west of the mountain Kulirag-met. On three sides the walls are remaining, the mountain to the east forming the other side

From north to south the extent is 600 paces (1425 ft.), and 390 (802 ft.) from west to east to the mountain on the south side, having no stairs on that side; average height about 18 ft. 7 in. On the north side it is 410 paces (926 ft.) from east to west, and the wall is 21 ft. high in some places. At the north-west corner of the wall, about 80 paces in extent westward, are some rocks before the principal staircase. On mounting the steps there is found a large platform 400 paces in extent towards the mountain. Along the wall on three sides a pavement extends for a width of 8 ft. The principal staircase A (*fig.* 23.) is not placed in the middle of the west side, but nearer to the north. It has a double flight, the distance between the flights at the bottom being 42 ft., and the width of them is 25 ft. 7 in. The steps are 4 in. high; and 14 in. wide. Fifty-five of them remain on the north side, and fifty-three on the south; and it is probable that some are buried by the ruins. The half spaces at the top of the first flight are 51 ft. 4 in. wide. The upper flights are separated from the lower by a wall which runs through at the upper landing. The upper flights are in forty-eight steps, and are cut out of single blocks of the rock. The upper landing is seventy-five feet between the flights.

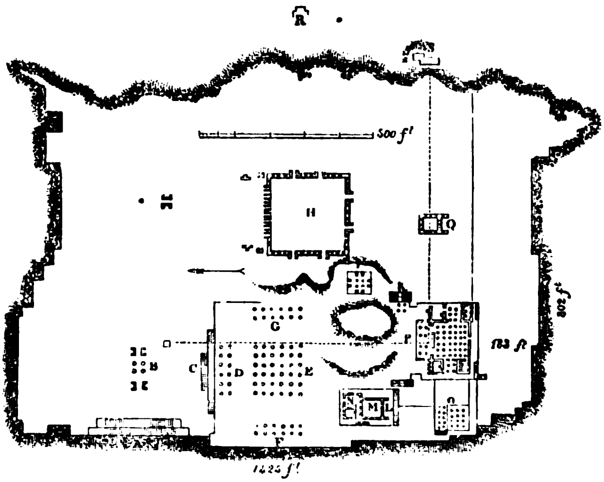


Fig. 23. PLAN OF PERSEPOLIS.

48. Forty-two feet from the landing, at B, are two large portals and two columns (originally four). The bottom of the first is covered with two blocks of stone, which fill two thirds of the space; the other third having been destroyed by time. The second portal is more covered by the earth than the first, by five feet. They are 22 ft. 4 in. deep, and 13 ft. 4. in. wide. On the interior side-faces of their piers, and nearly the whole length of them, are large figures of bulls, cut in bas-relief. The heads of these animals are entirely destroyed; and their breasts and fore feet project from the piers: the two of the first portal face to the staircase, and those of the other face towards the mountain. On the upper part of the piers there are some arrow-headed characters, too small to be made out from below. The remains of the first portal are 39 ft. high, and of the second 28 ft. The base of the piers is 5 ft. 2 in. high, and projects inwards; and the bases upon which the figures stand are 1 ft. 2 in. high. We may here observe that the figures on the further portal have the body and legs of a bull, an enormous pair of wings (*fig.* 24.) projecting from the shoulders, and the heads looking to the east show the faces of men. On the head is a cylindrical diadem, on both sides of which horns are clearly represented winding from the brows upwards to the front of the crown; the whole being surmounted with a sort of coronet, formed of a range of leaves like the lotus, and bound with a fillet carved like roses. The two columns (at Sir R. K. Porter's visit only one remained) are the most perfect among the ruins, and are 54 ft. high. At the distance of fifty-two feet south-eastward from the second portico is a water-trough cut out of a single stone 20 ft. long and 17 ft. 5 in. broad, and standing 3 ft. high from the ground. From hence to the northern wall of the platform is covered with fragments; and the remains of one column not channelled as the others are; this is 12 ft. 4 in. high.

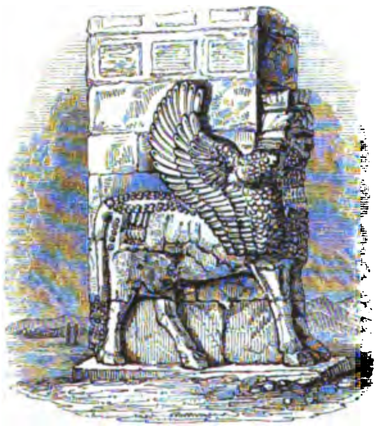


Fig. 24. FIGURE ON A PORTAL AT PERSEPOLIS.

49. At one hundred and seventy-two feet from the portals, southward, is another staircase of two flights (lettered C), one west and the other east. On the top of the ramp of the steps are some foliages, and a lion tearing to pieces a bull, in bas-relief, and larger than nature. This staircase is half buried. The western flight has twenty-eight steps, and the other, where the ground is higher, has only eighteen. These steps are 17 ft. long, 3 in. high, and 14½ in. wide. The wall of the landing is sculptured with three rows of figures, one above the other, and extending ninety-eight feet. The faces of these inner terrace walls are all decorated with bas-reliefs, of which *fig.* 25. is a specimen. On arriving at the top of this staircase, was found another large platform, paved with large blocks of stone; and at the distance of twenty-two feet two inches from the parapet of the landing, are the most northern columns (lettered D), originally twelve in number, whereof in Sir R. K. Porter's time only one remained. At seventy-one feet southward from these stood thirty-six columns more, at intervals of twenty-two feet two inches from each other, whereof only five now remain; the bases, however, of all the others are in their places, though most of them are much damaged. This group of columns is lettered E. To the east and west of the last-named group are two other groups of twelve each marked F and G, whereof five still remain in the eastern one, and four in the western one. The columns of the central group are fifty-five feet high; and those of the other three groups are sixty feet in height. To the south of the three groups of columns is situate the most raised building on these ruins. On the east, towards the mountain, a large mass of ruins is visible (lettered H), consisting of portals, passages, windows, &c. The first are decorated with figures on the interior; and the whole plot on which they stand is 95 paces from east to west, and about 125 paces from north to south. The centre part of the plot is covered with fragments of columns and other stones; and in the interior part there seems to have been a group of seventy-six columns, whereof none are represented by Sir R. K. Porter, nor are they shown in either of Le Bruyn's views. The highest building as to level, marked I, is 118 ft. distant from the columns lettered G. Some foundations are visible in front of this building, to which there is not the slightest trace of a staircase. At fifty-three feet from the façade of it to the right is a staircase of double flight, marked K, where again bassi relievi are to be found, near which are the remains of some portals which Le Bruyn thinks were destroyed by an earthquake. The next ruin (L) is 54½ ft. in extent, and has portals similar to those in other parts of the place. To its north, M exhibits uniform features, with windows, and what travellers have agreed to call niches, which are nothing more than square-headed recesses. Sculpture here again abounds, whereof we do not think a description necessary, as in *fig.* 25. a specimen of it has been given, sufficient to indicate its character. Behind this edifice is another, in some respects similar, except that it is thirty-eight feet longer. It is marked N on the plan. One hundred feet to the south of this last set of ruins (lettered O), Sir R. K. Porter seems to have found traces of columns, which, if we read Le Bruyn rightly, he does not mention. In this, the last-named traveller found a staircase leading to subterranean apartments, as he thought, but nothing of interest was discovered. The general dimensions of the building (P) extend about 160 ft. from north to south, and 190 ft. from east to west. It exhibits ten portals in ruins, besides other remains; and there are traces of thirty-six columns, in six ranks of six each. The spot is covered with fragments, under which have been traced conveyances for water. To the west of the last-named building was another entirely in ruins: to the east of it are visible the remains of a fine staircase, much resembling that first described, and which, therefore, we do not think it necessary to particularise, more than we do the numberless fragments scattered over the whole area, which was equal to nearly thirty English acres! The ruins at Q are of portals. At R and S are tombs cut in the rock, of curious form, but evidently, from their character, the work of those who constructed the enormous pile of building of which we have already inserted a representation. Between the leading forms of the portals of these ruins, or porticoes, as Le Bruyn calls them, and those of the structures of Egypt, there is a very striking resemblance. On comparison of the two, it is impossible not to be struck with the large crowning hollowed member, which seems to have been common to the edifices on the banks of the Nile and those on the plain of Merdasht. In both, this member, forming, as it were, an entablature, is ornamented with vertical ribs or leaves, and the large fillet above the hollow appears equally in each. In the walls of the Persepolitan remains, there is perhaps less real massiveness than in those which were the works of the Egyptians; but the similarity of appearance between them points to the conjecture that, though neither might have been borrowed from the other, they are not many removes from one common parent. The an-

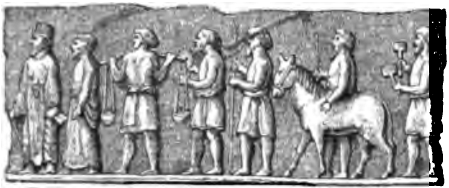


Fig. 25. BAS-RELIEF AT PERSEPOLIS.

nexed diagram (*fig.* 26.) will give the reader some notion of the style of the architecture of Persepolis. The diagram (*fig.* 27.) exhibits a specimen of a column and capital. *Fig.* 28. is a capital from one of the tombs. The walls forming the revêtement of the great esplanade are wonderfully perfect; and appear still capable of resisting equally the attacks of time and barbarism. The surface of the platform, generally, is unequal, and was of different levels: the whole seems to have been hewn from the mountain, from whence the marble has been extracted for constructing the edifices: hence the pavements appear masses of marble, than which nothing more durable or beautiful can be conceived. No cement appears to have been used, but the stones seem to have been connected by cramps, whose removal, however, has neither deranged the courses from which they have been removed, nor affected their nice fitting to each other; they are, indeed, so well wrought that the joints can scarcely be perceived, so close that the thinnest plate of metal could not be introduced between them.

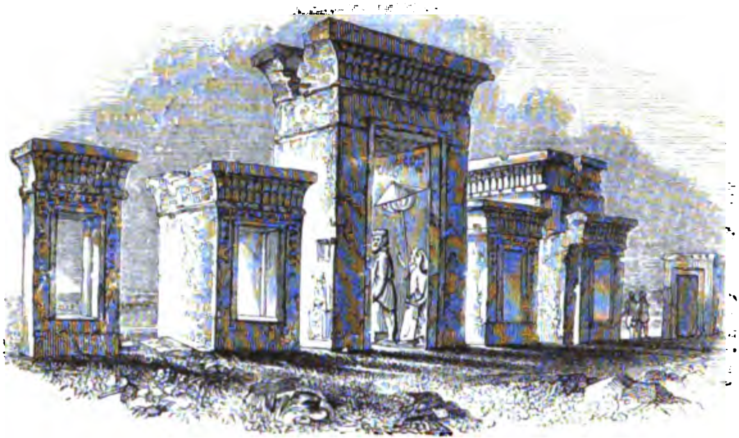


Fig. 26. ARCHITECTURE OF PERSEPOLIS.

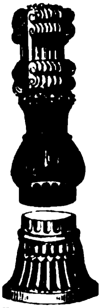


Fig. 27. COLUMN AND CAPITAL.

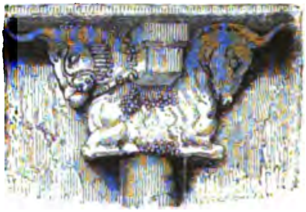


Fig. 28. CAPITAL FROM A TOMB.

50. No person can look at the style of composition and details of Persepolis without a conviction of some intimate connection between the architects of Persia and those of Egypt. The principles of both are identical; and without inquiring into the exact date of the monument whose description we have just left, there is sufficient to convince us that the theory started in respect of the Cyclopean architecture, of the arts travelling in every direction from some central Asiatic point, is fully borne out; and that the Egyptian style had its origin in Asia. We are quite aware that conjectures, bearing a semblance of probability, have assigned the erection of this stupendous palace to Egyptian captives, at a comparatively late period, after the conquest of Egypt by Cambyses; but we think they are answered by the similarity of arrow-headed characters used therein to those of ancient Babylon, whereof an example is here given (*fig.* 29.) from one of the portals of Persepolis. A few miles to the south of Persepolis, the excavated hill of Nakshi Rustân (*fig.* 30.) presents a number of sculptured

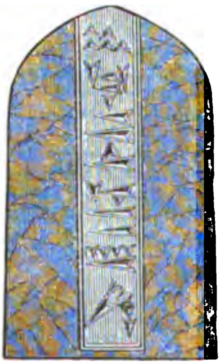


Fig. 29. ARROW-HEADED CHARACTERS.

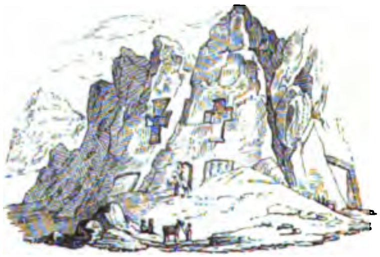


Fig. 30. NAKSHI RUSTAN.

tombs, the highest supposed to be coeval with Persepolis, and formed for the sepulture of the early kings of Persia. The lower tombs seem to have belonged to the Parthian Sassanide dynasties.

51. The present architecture of Persia much resembles that of other Mahometan countries. The city of Ispahan, in its prosperity, is said to have been surrounded by a wall twenty miles in circuit. When visited by Chardin, in 1666-7, the walls were so completely covered with houses as to be scarcely discernible; and he observes, that from whatever side the city is beheld it resembles a wood, where only domes are to be seen, with lofty slender towers attached to them. The houses are generally mean in external appearance: they commonly consist of a large square court surrounded with rooms of varying dimensions for different uses, the sides of the area being planted with flowers, and refreshed by fountains. Distinct from this is a smaller court, round which are distributed the apartments belonging to the females of the family; and almost every dwelling has a garden attached to it. The interior apartments of the richer classes are splendidly finished, though simply furnished. Those inhabited by the governor, public officers, and opulent merchants, may almost vie with palaces. Nearly all of them are constructed with sun-dried bricks, the public edifices only being built with burnt bricks: the roofs are mostly flat, having terraces, whereon the inhabitants sleep during several months of the year. According to the author above quoted, there were in his time within the walls 160 mosques, 48 colleges, 1802 caravanseras, 273 baths, 12 cemeteries, and 38,000 houses. But since that period the city has fallen into great ruin. The *Shah Meidan*, however (*figs.* 31. and 32.), or royal square, is still one of the largest and finest in the world. It is 440 paces in length, and 160 in breadth. On its south side stands the royal mosque, a magnificent building, erected by Shah Abbas, in the sixteenth century, and constructed of stone, covered with highly varnished bricks and tiles, whereon are inscribed sentences of the Koran. On another side of the Meidan is a Mahometan college called the Medresse Shah Sultan Hossein. The entrance is through a lofty portico decorated with twisted columns of Tabriz marble, leading through two brazen gates, whose extremities are of silver, and their whole surface sculptured and embossed with flowers, and verses from the Koran. Advancing into the court, on the right side is a mosque, whose dome is covered with lacquered tiles, and adorned externally with ornaments of pure gold. This, and the minarets that flank it, are now falling into decay. The other sides of the square are occupied, one, by a lofty and beautiful portico, and the remaining two by small square cells for students, twelve in each front, disposed in two stories. In the city are few hospitals; one stands, however, beside the caravanserai of Shah Abbas, who erected both at the same time, that the revenue of the latter might support the proper officers of the hospital. That the reader may have a proper idea of one of these inns of the

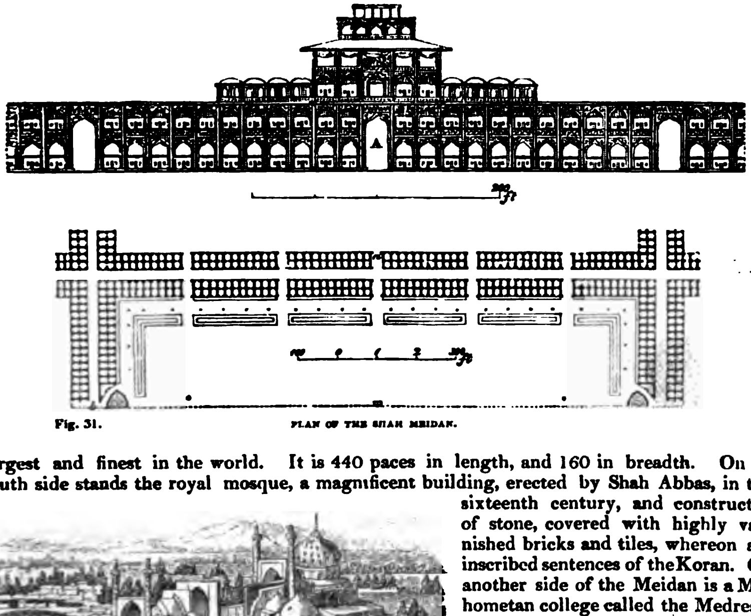


Fig. 31. PLAN OF THE SHAH MEIDAN.

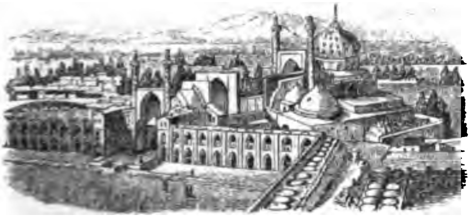


Fig. 32. THE SHAH MEIDAN.

East, if they may be so called, we have here given the plan of that just above named (*fig.* 33.). The palaces of the kings are enclosed in a fort of lofty walls, about three miles in circuit; in general the front room or hall is very open, and the roof supported by carved and gilded columns. The windows glazed with curiously stained glass of a variety of colours; each has a fountain in front. The palace of Chehel Sitoon, or forty pillars, is placed in the middle of an immense square, intersected by canals, and planted with trees. Towards the garden is an open saloon whose ceiling is borne by eighteen columns, inlaid with mirrors, and appearing at a distance to consist entirely of glass. The base of each is of marble, sculptured into four lions, so placed that the shafts stand on them. Mirrors are distributed on the walls in great profusion, and the ceiling is ornamented with gilt flowers. An arched recess leads from the apartment just described into a spacious and splendid hall, whose roof is formed into a variety of domes, decorated with painting and gilding. The walls are partly of white marble, and partly covered with mirrors, and are moreover decorated with six large paintings, whose subjects are the battles and royal fêtes of Shah Ismael and Shah Abbas the Great. Though of considerable age, the colours are fresh, and the gilding still brilliant. Adjoining the palace is the harem, erected but a few years ago. The bazaars are much celebrated; they consist of large wide passages, arched, and lighted from above, with buildings or stores on each side. One of these was formerly 600 geometrical paces in length, very broad and lofty. From these being adjacent to each other, a person might traverse the whole city sheltered from the weather. In Ispahan, we must not forget to notice that some fine bridges exist, which cross the river Zenderond.

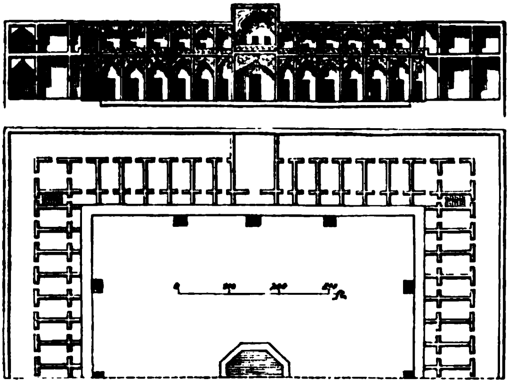


Fig. 33. CARAVANSERAI OF SHAH ABBAS.

Sect. V.

JEWISH ARCHITECTURE.

52. We are scarcely justified in giving a section, though short, to the architecture of the Jews, since the only buildings recorded as of that nation are the Temple of Jerusalem constructed by Solomon, and the house of the forest of Lebanon. The shepherd tribes of Israel, indeed, do not seem to have required such dwellings or temples as would lead them, when they settled in cities, to the adoption of any style very different from that of their neighbours. Whatever monuments are mentioned by them appear to have been rude, and have been already noticed in the section on Druidical and Celtic architecture. When Solomon ascended the throne, anxious to fulfil the wish his father had long entertained of erecting a fixed temple for the reception of the ark, he was not only obliged to send to Tyre for workmen, but for an architect also. Upon this temple a dissertation has been written by a Spaniard of the name of Villalpanda, wherein he, with consummate simplicity, urges that the orders, instead of being the invention of the Greeks, were the invention of God himself, and that Callimachus most shamefully put forth pretensions to the formation of the Corinthian capital which, he says, had been used centuries before in the temple at Jerusalem. The following account of the temple is from the sixth chapter of the First Book of Kings. Its plan was a parallelogram (taking the cubit at 1·824 ft., being the length generally assigned to it) of about 109½ ft. by 36½ ft., being as nearly as may be two thirds of the size of the church of St. Martin's in the Fields. In front was a pronaos, or portico, stretching through the whole front (36½ ft.) of the temple, and its depth was half its extent. The cell, or main body of the temple, was 54¾ ft. deep, and the sanctuary beyond 36½ cubits; the height of it being equal to its length and breadth. The height of the middle part, or cell, was 54¾ ft.; and that of the portico the same as the sanctuary, — that is, 36½ ft., — judging from the height of the columns. In the interior, the body of the temple was surrounded by three tiers of chambers, to which there was an ascent by stairs; and the central part was open to the sky. The ends of the beams of the floors rested on corbels of stone, and were not inserted into the walls, which were lined with cedar, carved into

cherubims and palm trees, gilt. In the sanctuary two figures of cherubs were placed, whose wings touched each other in the centre, and extended outwards to the walls. These were 10 cubits high. In the front of the portico were two pillars of brass, which were cast by Hiram, "a widow's son of the tribe of Naphtali," whose "father was a *man of Tyre*," and who "came to king Solomon and wrought all his work." These two pillars of brass (1 *Kings*, vii. 14, 15.) were each 18 cubits high, and their circumference was 12 cubits; hence their diameter was 3·82 cubits. The chapiters, or capitals, were 5 cubits high; and one of them was decorated with lilies upon a net-work ground, and the other with pomegranates. From the representation (*fig.* 34.) here given, the reader must be struck with their resemblance to the columns of Egypt with their lotus leaves, and sometimes net-work. In short, the whole description would almost as well apply to a temple of Egypt as to one at Jerusalem. And this tends, though slightly it is true, to show that the Phœnician workmen who were employed on the temple worked in the same style as those of Egypt.

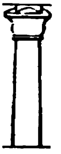


Fig. 34.

53. The house of the forest of Lebanon was larger than the temple, having been 100 cubits in length, by 50 in breadth; it also had a portico, and from the description seems to have been similar in style.

54. *Phœnician Architecture.* — That part of the great nation of Asia which settled on the coasts of Palestine, called in scripture Canaanites, or merchants, were afterwards by the Greeks called Phœnicians. Sidon was originally their capital, and Tyre, which afterwards became greater than the parent itself, was at first only a colony. From what we have said in a previous section on the walls of Mycene, it may be fairly presumed that their architecture partook of the Cyclopean style; but that it was much more highly decorated is extremely probable from the wealth of a people whose merchants were princes, and whose traffickers were the honourable of the earth. Besides the verses of Euripides, which point to the style of Phœnician architecture, we have the authority of Lucian for asserting that it was Egyptian in character. Unfortunately all is surmise; no monuments of Phœnicisn architecture exist, and we therefore think it useless to dwell longer on the subject.

Sect. VI.

INDIAN ARCHITECTURE.

55. Whence the countries of India derived their architecture is a question that has occupied abler pens than that which we wield, and a long period has not passed away since the impression on our own mind was, that the monuments of India were not so old as those of Egypt. Upon maturer reflection, we are not sure that impression was false; but if the arts of a country do not change, if the manners and habits of the people have not varied, the admission of the want of high antiquity of the monuments actually in existence will not settle the point. The capitals and columns about Persepolis have a remarkable similarity to some of the Hindoo examples, and seem to indicate a common origin; indeed, it is our opinion, and one which we have not adopted without considerable hesitation, that though the existing buildings of India be comparatively modern, they are in a style older than that of the time of their erection. Sir William Jones, whose opinion seems to have been that the Indian temples and edifices are not of the highest antiquity, says (3rd Discourse), "that they prove an early connection between India and Africa. The pyramids of Egypt, the colossal statues described by Pausanias and others, the Sphinx and the Hermes Canis (which last bears a great resemblance to the Varáhávatár, or the incarnation of Vishnu in the form of a boar), indicate the style and mythology of the same indefatigable workmen who formed the vast excavations of Canárah, the various temples and images of Buddha, and the idols which are continually dug up at Gayá or in its vicinity. The letters on many of these monuments appear, as I have before intimated, partly of Indian and partly of Abyssinian or Ethiopic origin; and all these indubitable facts may induce no ill-grounded opinion that Ethiopia and Hindustan were peopled or colonised by the same extraordinary race." In a previous page (*fig.* 27.), the reader will find a Persepolitan column and capital; we place before him, in *fig.* 35., an example from the Indra Subba which much resembles it in detail, and at the Nerta Chabei at Chillambaram are very similar examples. Between the styles of Persepolis and Egypt a resemblance will be hereafter traced, and to such an extent, that there seems no reasonable doubt of a common origin. The monuments of India may be divided into two classes, the *excavated* and *constructed*: the former being that where a building has been hollowed, or, as it were, quarried out of the rock; the latter, that built of separate and different sorts of materials, upon a regular plan, as may be seen in those buildings improperly called pagodas, which ornament the enclosures of the sacred edifices, of

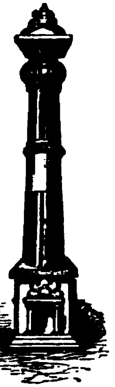


Fig. 35. A COLUMN OF THE INDRA SUBBA.

which they are component parts. The class first named seems to have interested travellers more than the last, from the apparent difficulty of execution; but on this account we are not so sure that they ought to create more astonishment than the constructed temple, except that, according to Daniel (*Asiat. Res.* vol. i.), they are hollowed in hard and compact granite.

56. The monuments which belong to the first class are of two sorts; those actually hollowed out of rocks, and those presenting forms of *apparently* constructed buildings, but which are, in fact, rocks shaped by human hands into architectural forms. Of the first sort are the caves of Elephanta and Ellora; of the last, the seven large pagodas of Mavalipowram. It will immediately occur to the reader that the shaping of rocks into forms implies art, if the forms be imposing or well arranged: so, if the hollowing a rock into well-arranged and well-formed chambers be conducted in a way indicating an acquaintance with architectural effect, we are not to assume that a want of taste must be consequent on the first sort merely because it cannot be called constructive architecture. And here we must observe, that we think the writer in the *Encyclopédie Méthodique* (art. Arch. Indienne) fails in his rèasoning; our notion being simply this, that as far as respects these monuments, if they are worthy to be ranked as works of art, the means by which they were produced have nothing to do with the question. It must, however, be admitted, that what the architect understands by ordonnance, or the composition of a building, and the proper arrangement of its several parts, points which so much engaged the attention of the Greeks and Romans, will not be found in Indian architecture as far as our acquaintance with it extends. Conjectures infinite might be placed before the reader on the antiquity of this species of art, but they would be valueless, no certain data, of which we are aware, existing to lead him in the right road; and we must, therefore, be content with enumerating some of the principal works in this style. The caves at Ellora consist of several apartments; the plan of that called the Indra Subba (*fig.* 36.) is here given, to show the species of plan which these places exhibit; and *fig.* 37. is a view of a portion of the interior of the same. The group of temples which compose these excavations are as follow: —

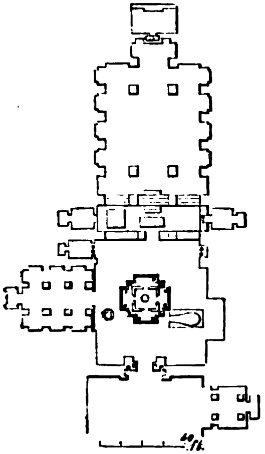


Fig. 36. PLAN OF THE INDRA SUBRA.

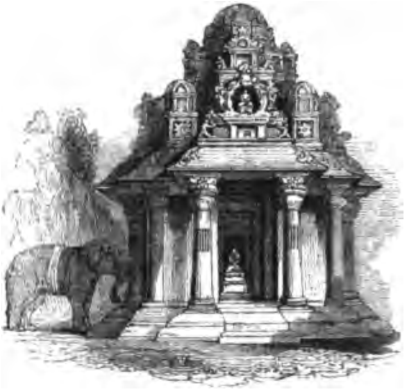


Fig. 37. VIEW INTO THE INTERIOR OF THE INDRA SUBBA.

Temple of Diagannâtha.	ft.	in.
External width of the excavation	57	0
Length (interior)	34	0
Width (ditto)	20	0
Height	13	0
Height of the pillars	11	0
Temple of Parocona.		
Length internally	35	0
Width	25	0
Height	8	0
Temple of Adi — Natha.		
Length	45	0
Height	9	0
Temple of Djenonasla.		
Width	11	0
Height	11	2
Temple of Domma — Leyma.		
Length	55	0
Width	18	6
Height	16	10

Temple of Indra.	ft.	in.
Length	54	0
Width	44	0
Height	27	0
Height of columns	22	0
Another Temple.		
Length	111	0
Width	22	4
Height	15	0
Temple of Mahadeo.		
Length	68	0
Width	17	0
Height	12	0
Temple of Ramichouer.		
Length	90	0
Height	15	0
Temple of Kailaça.		
Length	88	0
Height	47	0

57. The most celebrated excavated temple is that of Elephanta (*fig.* 38.), near Bombay, of whose interior composition the reader may obtain a faint idea from the subjoined representation (*fig.* 39.). It is 130 ft. long, 110 ft. wide, and 14½ ft. high. The ceiling is flat, and is apparently supported by four ranks of columns, about 9 ft. high, and of a balustral form. These stand on pedestals, about two thirds the height of the columns themselves. A great portion of the walls is covered with colossal human figures, forty to fifty in number, in high relief, and distinguished by a variety of symbols, probably representing the attributes of the deities whom they worshipped, or the actions of the heroes whom they represented. At the end of the cavern there is a dark recess, about 20 ft. square, entered by four doors, each flanked by gigantic figures. "These stupendous works," says Robertson, "are of such high antiquity, that, as the natives cannot, either from history or tradition, give any information concerning the time in which they were executed, they universally ascribe the formation of them to the power of superior beings. From the extent and grandeur of these subterraneous mansions, which intelligent travellers compare to the most celebrated monuments of human power and art in any part of the earth, it is manifest that they could not have been formed in that stage of social life where men continue divided into small tribes, unaccustomed to the efforts of persevering industry." Excavations similar to those we have named are found at Canárah, in the Island of Salsette, near Bombay. In these there are four stories of galleries, leading in all to three hundred apartments. The front is formed by cutting away one side of the rock. The principal temple, 84 ft. long, and 40 ft. broad, is entered by a portico of columns. The roof is of the form of a vault, 40 ft. from the ground to its crown, and has the appearance of being supported by thirty pillars, octagonal in plan, whose capitals and bases are formed of elephants, tigers, and horses. The walls contain cavities for lamps, and are covered with sculptures of human figures of both sexes, elephants, horses, and lions. An altar, 27 ft. high and 20 ft. in diameter, stands at the further end, and over it is a dome shaped out of the rock. Though the sculptures in these caves are low in rank compared with the works of Greek and Etrurian artists, yet they are certainly in a style superior to the works of the Egyptians; and we infer from them a favourable opinion of the state of the arts in India at the period of their formation. "It is worthy of notice," observes the historian we have just quoted, "that although several of the figures in the caverns at Elephanta be so different from those now exhibited in the pagodas as objects of veneration, that some learned Europeans

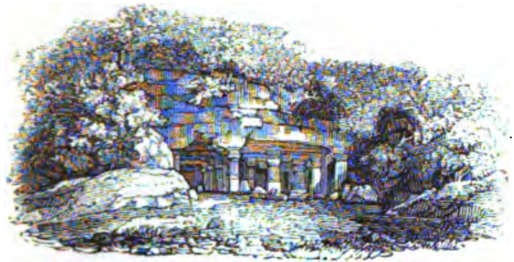


Fig. 38. TEMPLE OF ELEPHANTA.

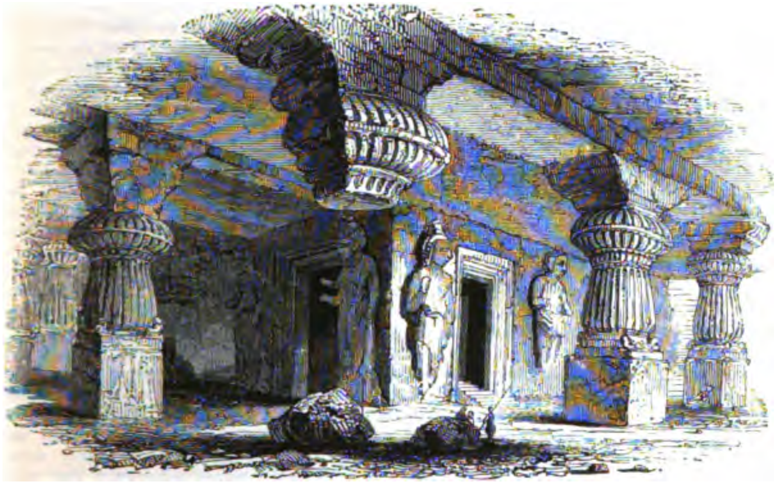


Fig. 39 INTERIOR OF THE TEMPLE OF ELEPHANTA.

have imagined they represent the rites of a religion more ancient than that now established in Hindostan; yet by the Hindoos themselves the caverns are considered as hallowed places of their own worship, and they still resort thither to perform their devotions, and honour the figures there, in the same manner with those in their own pagodas." Mr. Hunter, who in the year 1784 visited the place, considers the figures there as representing deities who are still objects of worship among the Hindoos. One circumstance justifying this opinion is, that several of the most conspicuous personages in the groups at Elephanta are decorated with the *zennar*, the sacred string or cord peculiar to the order of Brahmins, an authentic evidence of the distinction of casts having been established in India at the time when these works were finished.

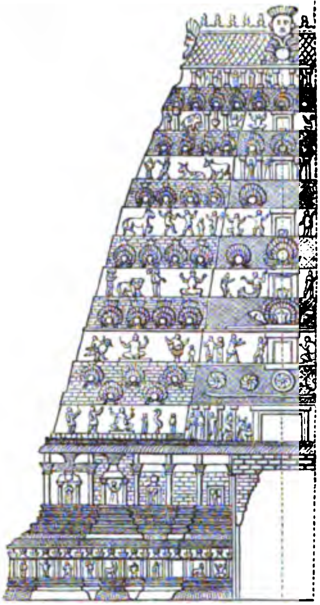


Fig. 40. PAGODA OF CHILLAMBARAM.

58. The structure of the earliest Indian temples was extremely simple. Pyramidal, and of large dimensions, they had no light but that which the door afforded; and, indeed, the gloom of the cavern seems to have led them to consider the solemn darkness of such a mansion sacred. There are ruins of this sort at Deogur and at a spot near Tanjore, in the Carnatic. In proportion, however, to the progress of the country in opulence and refinement, their sacred buildings became highly ornamented, and must be considered as monuments exhibiting a high degree of civilisation of the people by whom they were erected. Very highly finished pagodas, of great antiquity, are found in different parts of Hindostan, and particularly in its southern districts, where they were not subjected to the destructive fury of Mahometan zeal. To assist the reader in forming a notion of the style of the architecture whereof we are treating, we here place before him a diagram (*fig.* 40.) of part of the pagoda at Chillambaram, near Porto Novo, on the Coromandel coast; one which is, on account of its antiquity, held in great veneration. The monument would be perhaps more properly described as a cluster of pagodas, enclosed in a rectangular space 1332 ft. in length, and 936 ft. in width, whose walls are 30 ft. in height, and 7 ft. in thickness, each side being provided with a highly decorated frustum of a pyramid over an entrance gateway. The large enclosure is subdivided into four subordinate ones, whereof the central one, surrounded by a colonnade and steps, contains a piscina or basin for purification. That on the southern side forms a cloister enclosing three contiguous temples called *Chabei*, lighted only by their doors and by lamps. The court on the west is also claustral, having in the middle an open portico, consisting of one hundred columns, whose roof is formed by large blocks of stone. The last is a square court with a temple and piscina, to which is given the name of the Stream of Eternal Joy. To the temple is attached a portico of thirty-six columns, in four parallel ranks, whose central intercolumniation is twice the width of those at the sides, and in the centre, on a platform, is the statue of the Bull Nundu. It is lighted artificially with lamps, which are kept constantly burning, and is much decorated with sculpture. The central inclosure, on its eastern side, has a temple raised on a platform, in length 224 ft., and in width 64 ft., having a portico in front, consisting of a vast number of columns 30 ft. high; at the end of it a square vestibule is constructed with four portals, one whereof in the middle leads to the sanctuary, named *Nerta Chabei*, or Temple of Joy and Eternity, the altar being at the end of it. The temple is much decorated with sculpture, representing the divinities of India. The pilaster *fig.* 41. is placed at the sides of the door of the *Nerta Chabei*, and is extremely curious; but the most singular object about the building is a chain of granite carved out of the rock, attached to the pilasters, and supported at four other points in the face of the rock so as to form festoons. The links are about 3ft. long, and the whole length of the chain is 146 ft. The pyramids

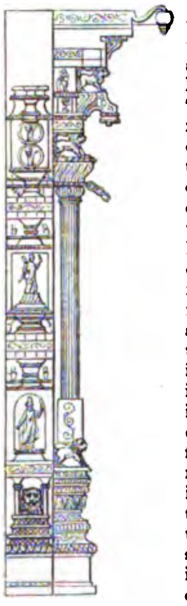


Fig. 41. PILASTER FROM THE NERTA CHABEI.

above mentioned, which stand over the entrances of the outer enclosure, rise from rectangular bases, and consist of several floors. The passage through them is level with the ground.

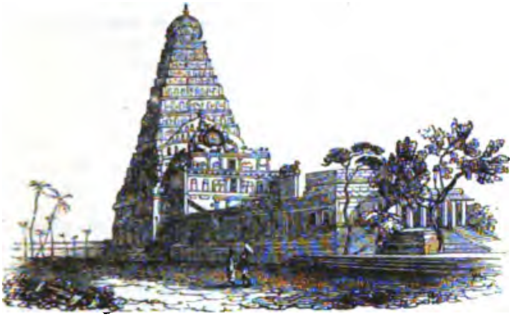


Fig. 42. PAGODA AT TANJORE.

59. A very beautiful example of the Indian pagoda exists at Tanjore, which we here insert (*fig.* 42.).

60. One of the largest temples known is that on the small island Seringham, near Trichinopoly, on the Coromandel coast. It is situate about a mile from the western extremity of the island, and is thus described by Sonnerat. It is composed of seven square enclosures, one within the other, the walls whereof are 25 ft. high, and 4 ft. thick. These enclosures are 350 ft. distant from one another, and each has four large gates with a high tower; which are placed, one in the middle of each side of the enclosure, and opposite to the four cardinal points. The outward wall is near four miles in circumference, and its gateway to the south is ornamented with pillars, several of which are simple stones, 33 ft. long, and nearly 5 ft. in diameter; and those which form the roof are still larger. In the inmost inclosures are the chapels. About half a mile to the east of Seringham, and nearer to the river Caveri than the Coleroon, is another large pagoda, called Jembikisma, but this has only one enclosure. The extreme veneration in which Seringham is held arises from a belief that it contains that identical image of the god Vishnu which used to be worshipped by Brahma.

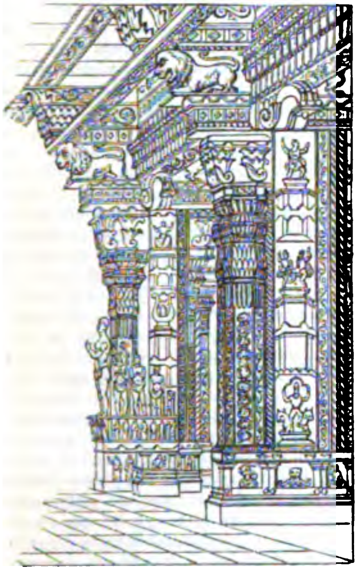


Fig. 43. TCHOULTRY AT MADURAH.

61. We shall conclude this section with some observations on Tchoultry (or Iun) at Madurah (*fig.* 43.). Its effect is quite theatrical, and its perfect symmetry gives it the appearance of a work of great art, and of greater skill in composition than most other Indian works. Yet an examination of the details, and particularly of the system of corbelling over, destroys the charm which a first glance at it creates. In it, the ornaments which in Grecian architecture are so well applied and balanced, seem more the work of chance than of consideration. We here insert an external view of the temple at this place (*fig.* 44.).

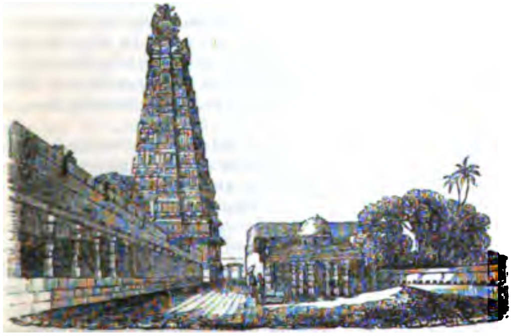


Fig. 44. TEMPLE AT MADURAH.

The essential differences between Indian and Egyptian architecture, in connection with the sculpture applied to them, have been well given in the *Encyclopédie Méthodique*, and we shall here subjoin them. In Egypt, the principal forms of the building and its parts preponderate, inasmuch as the hieroglyphics with which they are covered never interfere with the general forms, nor injure the effect of the whole; in India, the principal form is lost in the ornaments which divide and decompose it. In Egypt, that which is essential predominates; in India, you are lost in the multitude of accessories. In the Egyptian architecture, even the smallest edifices are grand; in that of India, the infinite subdivision into parts gives an air of littleness to the largest buildings. In Egypt, solidity is carried to the extreme; in India, there is not the slightest appearance of it.

Sect. VII.

EGYPTIAN ARCHITECTURE.

62. We propose to consider the architecture of Egypt — First, in respect of the physical, political, and moral causes which affected it. Secondly, in respect of its analysis and development. Thirdly, and lastly, in respect of the taste, style, and character which it exhibits.

63. I. In our introduction, we have alluded to the three states of life which even in the present day distinguish different nations of the earth — hunters, shepherds, and agriculturists; in the second class whereof are included those whose subsistence is on the produce of the waters, which was most probably the principal food of the earliest inhabitants of Egypt. Seated on the banks of a river whose name almost implies fertility, they would have been able to live on the supply it afforded for a long period before it was necessary to resort to the labours of agriculture. In such a state of existence nothing appears more probable than that they should have availed themselves of the most obvious shelter which nature afforded against the extremes of heat and cold, namely, the cavern; which, consisting of tufo and a species of white soft stone, was easily enlarged or formed to meet their wants. Certain it is, that at a very early period the Egyptians were extremely skilful in working stone, an art which at a later time they carried to a perfection which has never been surpassed. As the Tyrians, Sidonians, and other inhabitants of Palestine were, owing to the material which their cedar forests afforded, dexterous in joinery, so the Egyptians received an impulse in the style of their works from an abundance of the stone of all sorts which their quarries produced. Subterranean apartments, it will be said, are found in other countries; but they will mostly, India excepted, be found to be the remains of abandoned quarrries, exhibiting no traces of architecture, nor places for dwelling. Egypt, on the contrary, from time immemorial, was accustomed to hollow out rocks for habitation. Pliny (lib. xxxvi. c. 13.) tells us, that the great Labyrinth consisted of immense excavations of this sort. Such were the subterranean chambers of Biban el Melook, those which have in the present day received the name of the Labyrinth, and many others, which were not likely to have been tombs. When the finished and later monuments of a people resemble their first essays, it is easy to recognise the influential causes from which they result. Thus, in Egyptian architecture, every thing points to its origin. Its simplicity, not to say monotony, its extreme solidity, almost heaviness, form its principal characters. Then the want of profile and paucity of members, the small projection of its mouldings, the absence of apertures, the enormous diameter of the columns employed, much resembling the pillars left in quarries for support, the pyramidal form of the doors, the omission of roofs and pediments, the ignorance of the arch (which we believe to have been unknown, though we are aware that a late traveller of great intelligence is of a different opinion),—all enable us to recur to the type with which we have set out. If we pursue this investigation, we do not discover timber as an element in Egyptian compositions, whilst in Grecian architecture, the types certainly do point to that material. It is not necessary to inquire whether the people had or had not tents or houses in which timber was used for beams or for support, since the character of their architecture is specially influenced by the exclusive use of stone as a material; and however the form of some of their columns may not seem to bear out the hypothesis (such, for instance, as are shaped into bundles of reeds with imitations of plants in the capitals), all the upper parts are constructed without reference to any other than stone construction. It is, moreover, well known that Egypt was extremely bare of wood, and especially of such as was suited for building.

64. The climate of Egypt was, doubtless, one great cause of the subterranean style, as it must be in the original architecture of every nation. Materials so well adapted to the construction it induced, furnishing supports incapable of being crushed, and single blocks of stone which dispensed with all carpentry in roofs or coverings, a purity of air and evenness of temperature which admitted the greatest simplicity of construction from the absence of all necessity to provide against the inclemency of seasons, and which permitted the inscription of hieroglyphics even on soft stone without the fear of their disappearance, — all these concurred in forming the character of their stupendous edifices, and stimulated them in the development of the art.

65. The monarchical government, certainly the most favourable to the construction of great monuments, appears to have existed in Egypt from time immemorial. The most

important edifices with which history or their ruins have made us acquainted, were raised under monarchies; and we scarcely need cite any other than the ruins of Persepolis, of which an account is given in a previous section, to prove the assertion: these, in point of extent, exceed all that Egypt or Greece produced. Indeed, the latter nation sought beauty of form rather than immense edifices; and Rome, until its citizens equalled kings in their wealth, had no monuments worthy to be remembered by the historian, or transmitted as models to the artist.

66. Not the least important of the causes that combined in the erection of their monuments was the extraordinary population of Egypt: and though we may not perhaps entirely rely on the wonderful number of twenty thousand cities, which old historians have said were seated within its boundaries, it is past question that the country was favourable to the rearing and maintenance of an immense population. As in China at the present day, there appears in Egypt to have been a redundant population, which was doubtless employed in the public works of the country, in which the workman received no other remuneration than his food.

67. The Egyptian monarchs appear to have gratified their ambition as much in the provision for their own reception after this life as during their continuance in it. If we except the Memnonium, and what is called the Labyrinth at Memphis, temples and tombs are all that remain of their architectural works. Diodorus says, that the kings of Egypt spent those enormous sums on their sepulchres which other kings expend on palaces. They considered that the frailty of the body during life ought not to be provided with more than necessary protection from the seasons, and that the palace was nothing more than an inn, which at their death the successor would in his turn inhabit, but that the tomb was their eternal dwelling, and sacred to themselves alone. Hence they spared no expense in erecting indestructible edifices for their reception after death. Against the violation of the tomb it seems to have been a great object with them to provide, and doubts have existed on the minds of some whether the body was, after all, deposited in the pyramids, which have been thought to be enormous cenotaphs, and that the body was in some subterraneous and neighbouring spot. Other writers pretend that the pyramids were not tombs, assigning to them certain mystic or astronomical destinations. There are, however, too many circumstances contradictory of such an assumption to allow us to give it the least credit; and there is little impropriety in calling them sepulchral monuments, whether or not the bodies of the monarchs were ever deposited in them. The religion of Egypt, though not so fruitful, perhaps, as that of Greece in the production of a great number of temples, did not fail to engender an abundant supply. The priesthood was powerful and the rites unchangeable: a mysterious authority prevailed in its ceremonies and outward forms. The temples of the country are impressed with mystery, on which the religion was based. Here, indeed, Secresy was deified in the person of Harpocrates; and, according to Plutarch (*De Iside*), the sphinx, which decorated the entrances of their temples, signified that mystery and emblem were engrafted on their theology. Numerous doors closed the succession of apartments in the temples, leaving the holy place itself to be seen only at a great distance. This was of little extent, containing merely a living idol, or the representation of one. The larger portion of the temple was laid out for the reception of the priests, and disposed in galleries, porticoes, and vestibules. With few and unimportant variations, the greatest similarity and uniformity is observable in their temples, in plan, in elevation, and in general form, as well as in the details of their ornaments. In no country was the connection between religion and architecture closer than in Egypt, and as the conceptions and execution in architecture are dependent on the other arts, we will here briefly examine the influence which the religion of the country had upon them.

68. Painting and sculpture are not only intimately connected with architecture through the embellishments they are capable of affording to it, but are handmaids at her service in what depends upon taste, upon the principles of beauty, upon the laws of proportion, upon the preservation of character, and in various other respects. Nature, in one sense, is the model upon which architecture is founded; not as a subject of imitation, but as presenting for imitation principles of the harmony, proportion, effect, and beauty, for which the arts generally are indebted to nature. We think it was Madame de Staël who said that architecture was frozen music. Now, though in architecture, as in the other arts, there is no sensible imitation of nature, yet by a study of her mode of operating, it may be tempered and modified so as to give it the power of language and the sublimity of poetry. In respect of the connection of the art with sculpture, little need be said: in a material light, architecture is but a sculptured production, and its beauty in every country is in an exact ratio with the skill which is exhibited in the use of the chisel. Facts, however, which are worth more than arguments, prove that as is the state of architecture in a country, so is that of the other arts. Two things prevented the arts of imitation being carried beyond a certain point in the country under our consideration; the first was political, the other religious. The first essays of art are subjects of veneration in all societies; and when, as in Egypt, all change was forbidden, and a constant and inviolable respect was entertained for that which had existed be-

fore, when all its institutions tended to preserve social order as established, and to discourage and forbid all innovation, the duration of a style was doomed to become eternal. Religion, however, alone, was capable of effecting the same object, and of restraining within certain bounds the imitative faculty, by the preservation of types and primitive conventional signs for the hieroglyphic language, which, from the sacred purposes for which it was employed, soon acquired an authority from which no individual would dare to deviate by an improvement of the forms under which it had appeared. Plato observes, that no change took place in painting among the Egyptians; but that it was the same, neither better nor worse, than it had been ages before his time. *Σκοπων δ' εὑρησεις αυτοθι τα μυριοστον ετος γεγραμμενα, η τετυπωμενα (ουχ ὡς επος ειπειν μυριοστον, αλλ' οντως) των νυν δεδημιουργημενων ουτε τι καλλιονα, ουτ' αισχιω, την αυτην δε τεχνην απειργασμενα. — De Legibus*, lib. ii.

69. Uniformity of plan characterises all their works; they never deviated from the right line and square. "Les Egyptiens," observes M. Caylus "ne nous ont laissé aucun monument public dont l'elevation ait eté circulaire." The uniformity of their elevations is still more striking. Neither division of parts, contrast, nor effect is visible. All this necessarily resulted from the political and religious institutions whereof we have been speaking.

70. II. In analysing the architecture of Egypt, three points offer themselves for consideration, — construction, form, and decoration. In CONSTRUCTION, if solidity be a merit, no nation has equalled them. Notwithstanding the continued effect of time upon the edifices of the country, they still seem calculated for a duration equally long as that of the globe itself. The materials employed upon them were well adapted to insure a defiance of all that age could effect against them. The most abundant material is what the ancients called the Thebaic granite. Large quarries of it were seated near the Nile in Upper Egypt, between the first cataract and the town of Assouan, now Syene. The whole of the country to the east, the islands, and the bed of the Nile itself, are of this red granite, whereof were formed the obelisks, colossal statues, and columns of their temples. Blocks of dimensions surprisingly large were obtained from these quarries. Basalt, marble, freestone, and alabaster were found beyond all limit compared with the purposes for which they were wanted.

71. We have already observed, that Egypt was deficient in timber, and especially that sort proper for building. There are some forests of palm trees on the Lybian side, near Dendera (Tentyris); but the soil is little suited to the growth of timber. Next in quantity to the palm is the acacia; the olive is rare. With the exception of the palm tree, there is none suited for architectural use. The oak is not to be found; and that, as well as the fir which the present inhabitants use, is imported from Arabia. Diodorus says, that the early inhabitants used canes and reeds interwoven and plastered with mud for their huts; but he confines this practice to the country away from towns, in which, from fragments that have been found, we may infer that brick was the material in most common use.

72. Bricks dried in the sun were employed even on large monuments; but it is probable that these were originally faced either with stone or granite. The pyramids described by Pocock, called Ktoube el Meuschich, are composed of bricks, some of which are 13½ in. long, 6½ in. wide, and 4 in. thick; others 15 in. long, 7 in. wide, and 4½ in. thick. They are not united by cement, but in some instances cements of a bituminous nature were employed, and in others a mortar composed of lime or plaster and sand, of which it would seem that the second was exceedingly powerful as well as durable.

73. The Egyptians arrived at the highest degree of skill in quarrying and working stone, as well as in afterwards giving it the most perfect polish. In their masonry they placed no reliance on the use of cramps, but rather on the nice adjustment of the stones to one another, on the avoidance of all false bearings, and the nice balance of all overhanging weight. Of their mechanical skill the reader will form some idea by reference to volume iii. p. 328. of Wilkinson's *Manners and Customs of the Ancient Egyptians*, from a representation in a grotto at El Bersheh. A colossus on a sledge is therein pulled along by 172 men, but none of the mechanical powers seem to be called in to their assistance. "The obelisks," says Mr. Wilkinson, "transported from the quarries of Syene to Thebes and Heliopolis, vary in size from 70 to 93 ft. in length. They are of one single stone; and the largest in Egypt, which is that at the great temple at Karnak, I calculate to weigh about 297 tons. This was brought about 138 miles from the quarry to where it now stands; and those taken to Heliopolis passed over a space of 800 miles." Two colossi (one of them is the vocal Memnon), each of a single block 47 ft. in height, and containing 11,500 cubic feet, are carved from stone not known within several days' journey of the place; and at the Memnonium is a colossal statue, which, when entire, weighed 887 tons. We consider, however, the raising of the obelisks a far greater test of mechanical skill than the transport of these prodigious weights; but into the mode they adopted we have no insight from any representations yet discovered. We can scarcely suppose that in the handling of the weights whereof we have spoken, they were unassisted by the mechanical powers, although, as we have observed, no representations to warrant the conjecture have been brought to light.

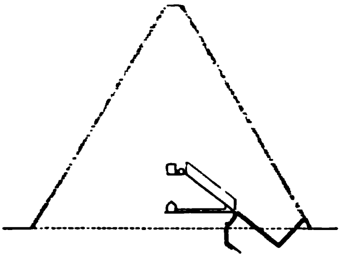


FIG. 45. SECTION OF PYRAMID OF CHEOPS.

74. In the construction of the pyramids it is manifest they would serve as their own scaffolds. The oldest monuments of Egypt of which we below give a view, and a section of that of the largest, called of Cheops (*fig.* 45.), are the pyramids at Gizeh, to the north of Memphis. Mr. Wilkinson supposes them to have been erected by Suphis and Jeusuphis his brother, 2120 years B. C., that is, previous by nearly 400 years to the entrance of Joseph into Egypt; but the same author admits that, previous to the reign of Osirtasen, 1740 B. C., there is nothing to guide any one with certainty as to dates. The edifices (*fig.* 46.), however, more commonly known by the names of Cheops, Cephrenes, and Mycerinus, are extraordinary for their size and the consequent labour bestowed upon them; but as works of the art they are of no further importance than being a link in the chain of its history. They are constructed of stone from the neighbouring mountains, and are in steps, of which in the largest there are two hundred and eight, varying in height from 2½ ft. (French) to 4 ft., decreasing in height as they rise towards the summit. Their width diminishes in the same proportion, so that a line drawn from the base to the summit touches the edge of each step. So great a difference in the measures by different authors appears, that we here subjoin those of the pyramid of Cheops: —

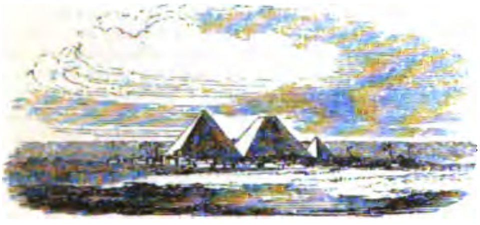


FIG. 46. PYRAMIDS OF GIZEH.

Authors.	*Length of base.*	*Number of steps.*	*Height.*
Herodotus	800 Greek ft.		852 English ft.
Strabo	600 —		666 —
Diodorus	700 —		639 —
Sandys	300 paces		
Bellonius	324 —		
Greaves	693 English ft.	207	499 —
Le Bruyn	750 —		656 —
Prosper Alpinus	799 —		666 —
Thevenot	727 —	208	554 —
Niebuhr	757 —		469 —
Chazelles	751 —		498 —
Maillet		208	
Pocock		212	
Belon		250	
French Engineers			477 —

Upon the top thereof is a platform 32 ft. square, consisting of nine large stones, each about a ton in weight, though inferior in that respect to others in the edifice, which vary from 5 ft. to 30 ft. in length, and from 3 ft. to 4 ft. in height. From this platform Dr. Clarke saw the pyramids of Saccara to the south, and on the east of them smaller monuments of the same kind nearer to the Nile. He remarked, moreover, an appearance of ruins which might be traced the whole way from the pyramids of Gizeh to those of Saccara, as if the whole had once constituted one great city. The stones of the platform are soft limestone, a little harder and more compact than what in England is called *clunch*. The pyramids are built with common mortar externally, but no appearance of mortar can be discerned in the more perfect parts of the masonry. The faces of the pyramid are directed to the four cardinal points. The entrance is in the north front, and the passage to the central chamber is shown on the preceding section. That in the pyramid of Cephrenes (*fig.* 47.) is thus described by Belzoni: — The first passage is built of granite, the rest are cut out of the natural sandstone rock which rises above the level of the basis of the pyramid. This passage is 104 ft. long, 4 ft. high, and 3 ft. 6 in. wide; descending at an angle of 26 degrees: at the bottom is a portcullis, beyond which is a horizontal passage

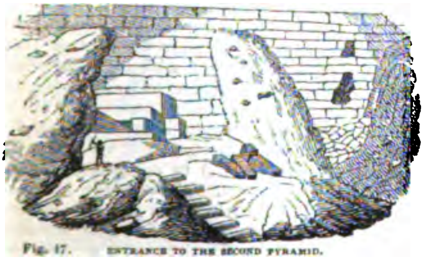


FIG. 47. ENTRANCE TO THE SECOND PYRAMID.

of the same height as the first, and at the distance of 22 ft. it descends in a different direction, leading to some passages below. Hence it re-ascends towards the centre of the pyramid by a gallery 84 ft. long, 6 ft. high, and 3 ft. 6 in. wide, leading to a chamber also cut out of the solid rock. The chamber is 46 ft. in length, 16 feet wide, and 23 ft. 6. in. in height, and contained a sarcophagus of granite 8 ft. long, 3 ft. 6. in. wide, and 2 ft. 3 in. deep in the inside. Returning from the chamber to the bottom of the gallery a passage descends at an angle of 26 degrees to the extent of 48 ft. 6 in., when it takes a horizontal direction for a length of 55 ft.; it then again ascends at the same angle and proceeds to the base of the pyramid, where another entrance is formed from the outside. About the middle of the horizontal passage there is a descent into another chamber, which is 32 ft. long, 10 ft. wide, and 8 ft. 6 in. high. The dimensions of this pyramid, as given by Denon, are a base of 655 ft. and a height of 398 ft. Those of the pyramid of Mycerinus are a base of 280 ft., and a height of 162 ft. The pyramids of Saccara, which are as many as twenty in number, vary in form, dimensions, and construction. They extend five miles to the north and south of the village of Saccara. Some of them are rounded at the top, and resemble hillocks cased with stone. One is constructed with steps like that of Cheops. They are six in number, each 25 ft. high, and 11 ft. wide The height of one in the group is 150 ft. Another, built also in steps, is supposed to be as high as that of Cheops. The stones whereof they are composed are much decayed, and more crumbling than those of Gizeh; hence they are considered older. One of them is formed of unburnt bricks, containing shells, gravel, and chopped straw, and is in a very mouldering state. About 300 paces from the second pyramid stands the extraordinary gigantic statue of the Sphinx (*fig.* 48.), whose length from the fore-part to the tail has been found to be 125 ft. Belzoni cleared away the sand, and found a temple held between the legs and another in one of its paws. According to Denon, the antiquity of the Egyptian temples may be comparatively determined from their size; the larger ones being posterior to the smaller. Since, however, the wonderful insight we have obtained into the meaning of the hieroglyphics, more accurate information than we before possessed may be gained on that point by reference to Mr. (now Sir Gardiner) Wilkinson's works on Egypt and Thebes. A spirit of simplicity, grandeur, and solidity reigns through the whole of them, and every precaution seems to have been taken to render them eternal. The walls by which they are enclosed are found sometimes 26 ft. in thickness, and those of the entrance gate of a temple at Thebes are as much as 53 ft. thick at their base, and are composed of blocks of enormous size. The masonry employed is that called by the Greeks emplectum (εμπλεκτον), all filling in of an inferior or rubble work being discarded. They are masses of nicely squared and fitted stones, and are built externally with a slope like the walls of a modern fortification. The columns are absolutely necessary for the support of the ceilings, which consist of large blocks of stone, and are therefore of few diameters in height. Sometimes they are in a single piece, as at Thebes and Tentyris. The stones of which the ceilings are composed are usually, according to Pococke, 14 ft. long, and 5½ ft. in breadth, but some run much larger.

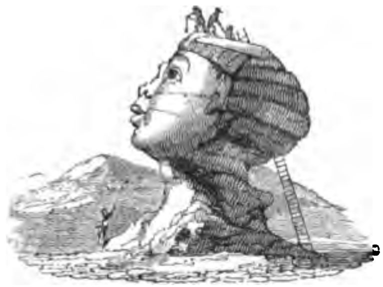


Fig. 48. THE SPHINX.

75. Before adverting to the form and disposition of the Egyptian temple, we think it here necessary to notice the recent discovery of an arch in a tomb at Saccara, said to be of the time of Psammeticus II., and of one also at Thebes in the remains of a crude brick pyramid. (See *Wilkinson's Customs of the Ancient Egyptians*, vol. iii. p. 263. 321.) That exhibited in the tomb of Saccara, from the vignette given, is clearly nothing but a lining of the rock, and is, if truly represented in the plate, incapable of bearing weight, which is the office of an arch. That, however, at Thebes, to which Mr. W. assigns the date of 1500 B.C., with every respect for his great information on the subject, and with much deference to his judgment, not having ourselves seen it, we cannot easily believe to be of such antiquity. Its appearance is so truly Roman, that we must be permitted to doubt the truth of his conjecture. We are, moreover, fortified in the opinion we entertain by the principles on which the style of Egyptian architecture is founded, which are totally at variance with the use of the arch. We have ventured to transfer this (*fig.* 49.) to our pages, that the reader may form a judgment on the subject, as well as ourselves. We will only add, that the reasons assigned by Mr. W. for the Egyptians not preferring such a mode of construction as the arch, because of the difficulty of repairing it when injured, and the consequences attending the decay of a single block, are not of any weight with us, because, practically, there is an easy mode of accomplishing such repair. And, again, the argument that the superincumbent weight applied to an arch in such a case as that before

us will not hold good, inasmuch as the balance on the back of each course would almost preserve the opening without any arch at all.

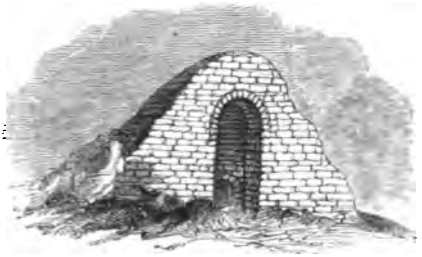


Fig. 49. ARCH AT THEBES.

76. The form and disposition of the Egyptian temple seem to have been founded on immutable rules. The only points wherein they differ from one another are in the number of their subdivisions and their extent, as the city for which they served was more or less rich. Unlike the temples of the Greeks and Romans, whose parts were governed by the adoption of one of the orders, and whose whole, taken in at a single glance, could be measured from any one of its parts: those of Egypt were an assemblage of porticoes, courts, vestibules, galleries, apartments, communicating with each other, and surrounded with walls. Strabo, in his 17th book, thus describes the temples in question. "At the entrance of the consecrated spot the ground is paved to the width of 100 ft. (πλεθρον) or less, and in length three or four times its width, and in some places even more. This is called the court (δρομος, course); thus Callimachus uses the words —

'Ο δρομος ἱερος αὐτος Ανουβιδος.

Throughout the whole length beyond this on each side of the width, are placed sphinxes of stone, 20 cubits or more distant from one another, one row being on the right, and the other on the left. Beyond the sphinxes is a great vestibule (προπυλον), then a further one, and beyond this another. The number, however, of the sphinxes, as of the vestibules, is not always the same, but varies according to the length and breadth of the course. Beyond the vestibules (προπυλαια) is the temple (νεως), having a very large porch (προναος), which is worthy to be recorded. The chapel (σηκος) is small, and without a statue; or, if there be one, it is not of human form, but that of some beast. The porch on each side has a wing (πτερα); these consist of two walls as high as the temple itself, distant from each other at the bottom a little more than the width of the foundations of the temple, then they incline towards each other, rising to the height of 50 or 60 cubits. These walls are sculptured with large figures, similar to those which are to be seen in the works of the Etruscans and ancient Greeks." This account is not at all exaggerated, as we shall immediately show by the introduction in this place of the plan, section, and elevation of the celebrated temple at Apollonopolis Magna, between Thebes and the first cataract, which, though, as we learn from the deciphering in these days, the hieroglyphics upon it are not of the time of the Pharaohs, seems admirably calculated to give the reader almost all the information necessary for understanding the subject. This will, moreover, so much more fully explain it than words, that we shall not need to do more than afterwards come to some recital of the details.

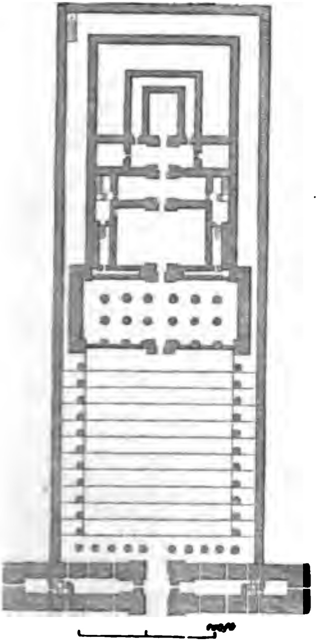


Fig. 50. PLAN OF TEMPLE AT APOLLONOPOLIS MAGNA.

77. This edifice, seated near Edfou, about twenty miles south of Thebes, is one of the largest in Egypt, and is comparatively in good preservation. Its form is rectangular, and its general dimensions 450 ft. by 140 ft. (*fig.* 50.) In the centre of one of the short sides is the entrance, which consists of two buildings, each 100 ft. long, and 32 ft. in width; both pyramidal in form, and lying in the same direction, but separated by a passage 20 ft. in width, with a doorway at each extremity. This passage conducts us to a quadrangle 140 ft. long, and 120 ft. wide, flanked by twelve columns on each side, and eight more on the entrance side, all standing a few feet within the walls, and thus forming a colonnade round three sides covered by a flat roof. A view of a portion of it is given in *fig.* 54. At the further end of the quadrangle (which rises by corded steps) opposite to the entrance, is a portico extending the whole breadth of the quadrangle, and 45 ft. in depth. It has three ranks of columns, containing six in each rank, is covered by a flat roof, is 45 ft. deep, and is enclosed by walls on three sides, the fourth, or that opposite the entrance,

being open. This is, however, closed breast high by a species of pedestals half inserted in the columns, and in the central intercolumniation a doorway is constructed with piers, over which are a lintel and cornice cut through. From this portico a doorway leads to an inner vestibule, in which are three ranks of four columns each, smaller than those first described, but distributed in the same way. Beyond this, in Cousin's plan, are sundry apartments, with staircases and passages, whereof the smaller central one was doubtless the cell. *Fig.* 51. is a longitudinal section. *Fig.* 52. is the elevation. We may here add, that there is so little difference between the earlier and later specimens of Egyptian architecture, that though, as we have hinted, this is of the latter, it will convey a pretty correct knowledge of all. The general appearance of the temple is given in *fig.* 53., and a view of the interior in *fig.* 54. The plan of the Egyptian temple is always uniform, symmetrical, and rectangular. Its most brilliant feature is the great number of columns employed, in which is displayed a prodigality unapproached by any other nation. This, however, was induced by the necessity for employing blocks of stone for the ceilings or roofs. The greatest irregularity occurring in any of the plans known, is in that at the island of Philæ (see *fig.* 55.), and it is very evident that the cause was the shape of the ground on which it is placed. The intercolumniations were very small, rarely exceeding a diameter, or one diameter and a half of the column. We know of no specimens of peripteral temples similar to those of Greece, that is, those in which the cell is surrounded by columns. In the elevations of those of Egypt, the spirit and character of their architecture is more particularly developed. But they are monotonous. The repetition of the same forms is carried to the utmost pitch of tolerance. The pyramidal form prevails in all the combinations, whether in walls, doors, general masses, or details. In considering the principal parts of the elevations, the first feature that presents itself is the column, which we will notice without its attendant base and capital. If it were possible to establish a system relative to their invention and subsequent perfection, we might easily arrange them in distinct classes, principally as respects their decoration; but as far as regards general form, the Egyptian column may be reduced to two varieties, the circular and polygonal. The first are of two sorts. Some are found quite plain or smooth, but ornamented with hieroglyphics (see *fig.* 56.). Some

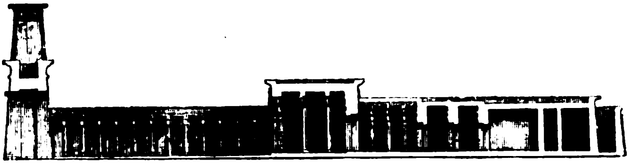


Fig. 51. LONGITUDINAL SECTION OF TEMPLE AT APOLLONOPOLIS.

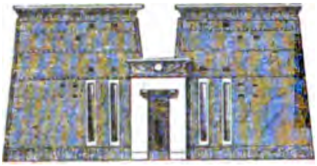


Fig. 52. ELEVATION.

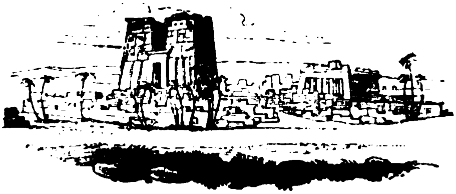


Fig. 53. VIEW OF THE TEMPLE.

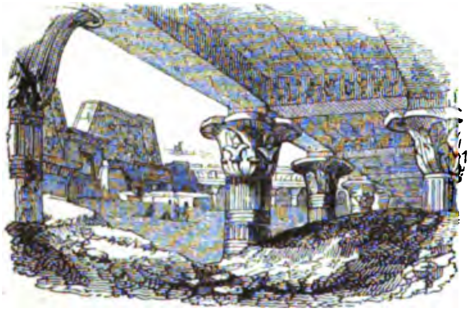


Fig. 54. VIEW OF THE INTERIOR.

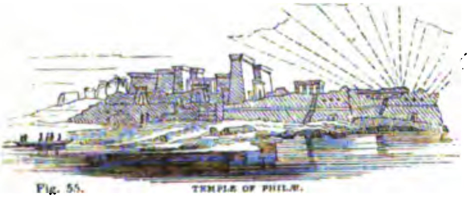


Fig. 55. TEMPLE OF PHILÆ.

are composed with ranges of horizontal circles, and look like an assemblage of bundles of rods tied together at intervals. The only difference among those columns which are circular and plain is in their having hieroglyphics, or not. Of the second sort there are many varieties, of which we here present three specimens (*fig.* 57.). They have the appearance of being bound together by hoops, like barrels. These are usually in three rows with four or five divisions in each; but these arrangements seem to have been subject to no certain laws. The species of columns in question is certainly curious, and appears based upon the imitation of stems of trees bound together, so as out of a number to form one strong post. It seems scarcely possible that they could have had their origin in mere whim or caprice. Many polygonal columns are to be found in Egypt. Some square specimens are to be seen in the grottos at Thebes cut out of the rock itself. Similar examples occur at the entrance of the sanctuary of a temple in the same city. Hexagonal ones are described by Norden, and Pocock mentions one of a form triangular on the plan. We do not at present remember any fluted specimen, except in the tombs of Beni-Hassan, of which a representation will be given in the section on Grecian architecture. Their character is shortness and thickness. They vary from three to eleven feet in diameter, the last dimension being the largest diameter that Pocock observed, as in height the tallest was forty feet. Such were some of those he measured at Carnac and Luxor, but this he gives only as an approximation from the circumstance of so much of them being buried in the earth.

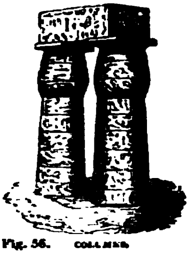


Fig. 56. COLUMNS.

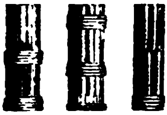


Fig. 57. SHAFTS.

78. Pilasters, properly so called, are not found in Egyptian architecture. The base of the column, when it appears, is extremely simple in its form. Among the representations in Denon's work is one in which the base is in the shape of an inverted ogee. It belongs to a column of one of the buildings at Tentyris.

79. In their capitals, the Egyptians exhibited great variety of form. They may, however, be reduced to three species, — the square, the vase-formed, and the swelled. The first (*fig.* 58.) is nothing more than a simple abacus, merely placed on the top of the shaft of the column, to which it is not joined by the intervention of any moulding. This abacus is, however, sometimes high enough to admit of a head being sculptured thereon, as in the annexed block. It does not appear, as in Grecian architecture, that in that of Egypt differently proportioned and formed columns had different capitals assigned to them. The notion of imparting expression to architecture by a choice of forms of different nature, and more or less complicated according to the character of an order, was unknown in Egypt. It was an architectural language which the people knew not. The vase-shaped capital (*fig.* 59.) is variously modified: sometimes it occurs quite plain; in other cases it is differently decorated, of which we here give two examples. It certainly has all the appearance of having afforded the first hint for the bell of the Corinthian capital. The third or swelled capital is also found in many varieties; but if the form be not founded on that of the bud of a tree, we scarcely know wherein its original type is to be sought. Two examples of it are here appended.

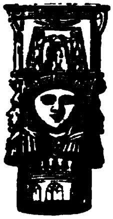


Fig. 58. CAPITAL.

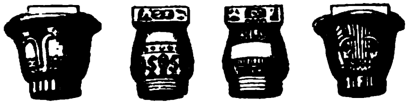


Fig. 59. VASE AND OTHER SHAPED CAPITALS.

80. The entablature, for such (however unlike it be to the same thing in the architecture of Greece) we suppose we must call the massive loading placed on the walls and columns of ancient Egypt, is very little subdivided. The upper part of it, which we may call the cornice, projects considerably, having a large concave member, in some cases consisting of ornaments representing a series of reeds parallel to each other from top to bottom; in other cases in groups of three or six in a group, the intervals between them being sculptured with winged globes, as on the portico of the temple at Tentyris, given in *fig.* 60. Sculptures of animals, winged globes, and scarabæi, are the almost constant decorations placed on what may be called the architrave of the Egyptian temple. Of the winged globe, usually found on the centre of it, as also of the great concave cornice, *fig.* 61. is a representation. We close our observations on the cornices of the Egyptian temple by requesting the reader, if he have the smallest doubt on the common origin of the archi-

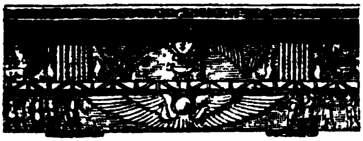


Fig. 60. ENTABLATURE.

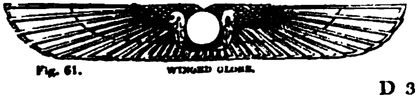


Fig. 61. WINGED GLOBE.

tectures of Egypt and Persepolis, to refer to *fig.* 26., where he will find a precisely similar use of the great cavetto which crowned the buildings of both countries. The writer who, in the *Description Abrégée des Monumens de la Haute Egypt*, has found that this great curve is borrowed from the bending leaves of the palm tree, has mistaken the elements of decoration for substantial constructive art, and has forgotten that the first object follows long after the latter. But we doubt if he really meant what his words import. The ceilings of Egypt are invariably monotonous. The non-use of the arch, whereon we have touched in a preceding page, and the blocks of stone which the country afforded, allowed little scope for display of varied form. In the colonnades of the country, architraves of stone rest on the columns (see *fig.* 54.), on which transversely are placed those which actually form the ceilings, just like the floor boards of a modern economical English building. On them are often found some of the most interesting representations that are in existence: we allude to those of the zodiacal constellations disposed circularly about the centre of the apartments in which they are placed. Though nothing has been deduced from these to satisfy us on the date of their continent buildings, they are not the less unworthy of further investigation, which, however, it is not our province here to pursue.

81. The gates and portals of the Egyptian temples were either placed, as at Carnac and Luxor (*figs.* 62. and 63.), in masses of masonry, or between columns, as already noticed, inclined upwards, having generally a reed moulding round them, and the whole crowned with a large cavetto. They were plentifully covered with hieroglyphics; frequently fronted by a pair of obelisks; and on their sides were placed staircases of very simple construction, leading to platforms on their summits. It is now difficult to account for the extraordinary labour bestowed on these masses of masonry. More than pictorial effect must have been the motive. The reader will, by turning back to *fig.* 52., be equally surprised with ourselves when he contemplates, in the gateway at the Temple of Apollinopolis Magna, such vast efforts developed on so apparently minor a point. The masses in these are always pyramidal, and bear great resemblance to the gates of modern fortifications. Sometimes they are extremely simple, and do not rise so high as the adjacent buildings which flank them. Their thickness is enormous, some of them extending to the extraordinary depth of fifty feet.

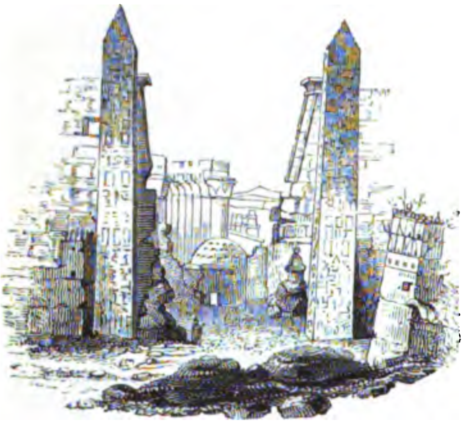


Fig. 62. EGYPTIAN PORTAL AT LUXOR.

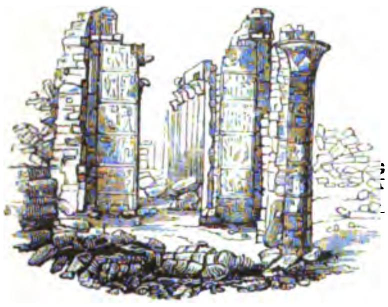


Fig. 63. EGYPTIAN PORTAL AT CARNAC.

82. Windows were not frequently used. When they occur they are long small parallelograms, rarely ornamented, but splayed inside. Many of the apartments were without windows at all.

83. We have, in a previous page, alluded to the Pyramids; to which we here add, that, whatever might have been their purpose, it is certain that the form adopted in them — one that, among other people, was devoted to the purposes of sepulture—was of all architectural forms that calculated to ensure durability, and was, moreover, well suited to the views of a nation which took extraordinary means to preserve the body after life, and expended large sums on their tombs.

84. Ornament or Decoration may be considered under two heads, — that which consists in objects foreign to the forms of the edifices themselves, such as statues, obelisks, &c.; and that which is actually affixed to them, such as the carving on the friezes, bas-reliefs, &c.

85. The former of these are remarkable for the size and beauty of the materials whereof they are composed. First for notice are their statues of colossal dimensions, which are mostly, if not always, in a sitting attitude. The two here given (*fig.* 64.) are from the Memnonium.

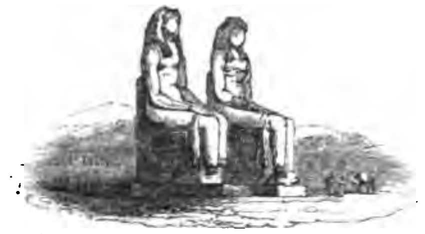


Fig. 64. COLOSSAL STATUES FROM THE MEMNONIUM.

They are generally isolated, and placed on simple pedestals. The use of Caryatides, as they are called, perhaps improperly, in Egyptian architecture, if we may judge from remains, does not appear to have been very frequent. In the tomb of Osymandyas, we find, according to Diodorus, that there was a peristylium, 400 feet square, supported by animals 16 cubits high, each in one stone, instead of columns. The same author (vol. i. f. 56. ed. Wesseling), speaking of Psammeticus, says, "Having now obtained the whole kingdom, he built a propylæum, on the east side of the temple, to the God at Memphis; which temple he encircled with a wall; and in this propylæum, instead of columns, substituted colossal statues 12 cubits in height." Statues of sphinxes in allies or avenues were used for ornamenting the dromos of their temples. Of this species of ornament the ruins of Thebes present a magnificent example. They were placed on plinths facing one another, and about ten feet apart. Examples of lions also occur. The form of the Egyptian obelisks is too well known to need a description here. They have been alleged to be monuments consecrated to the sun. From the situation they often occupy, it is clear they were used neither as gnomons nor solar quadrants.

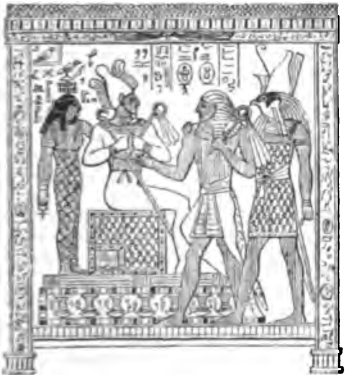


Fig. 65. PRESENTATION TO OSIRIS.

86. Amongst the ornaments affixed to their buildings, or rather forming a part of them, the most frequent are hieroglyphics and bas-reliefs. The custom of cutting the former upon almost every building was, as we now find, for the purpose of record; but it is nevertheless to be considered as ornamental in effect. The figures that are sculptured on the walls of the temples are mostly in low relief, and are destitute of proportion; and, when in groups, are devoid of sentiment. Painting was another mode of decoration. The grottoes of the Thebaid, and other subterranean apartments, abound with pictures, not only of hieroglyphics, but of other subjects. But the taste of all these, either in drawing, colouring, or composition, is not better than that of their sculpture. (See an example in *fig.* 65.) Yet in both these arts, from the precision with which they are cut and the uniformity of line and proportion they exhibit, a certain effect is produced which is not altogether displeasing.

87. The nymphæa lotus, or water lily, seems to have been the type of much of the ornament used for the purpose of decoration. The leaf of the palm tree was another object of imitation, and is constantly found in the capitals of their columns. The use of the palm leaf in this situation may have been derived from a popular notion mentioned by Plutarch, (*Symposiac.* lib. vi. cap. 4.), that the palm tree rose under any weight that was placed upon it, and even in proportion to the degree of depression it experienced. This supposed peculiarity is also mentioned by Aulus Gellius (lib. iii. cap. 6.). The reed of the Nile, with its head, enters into some combinations of ornament; the former, indeed, collected in bundles, seems to have been the type of some of the species of their columns. In their entablatures and elsewhere, animals of all sorts occasionally find a place as ornaments, even down to fishes, which occur in a frieze at Assouan; and, as we have before observed, there are few buildings of importance in which the winged globe does not appear as an ornament.

88. Some observations on the taste, style, and character of Egyptian architecture, will conclude this section. If the type was, as we imagine, derived from the early subterranean edifices of the people, whose customs allowed of no change or improvement, we cannot be surprised at the great monotony that exists in all their monuments. The absence of variety in their profiles, by means of projecting and re-entering parts, of the use of the arch, of the inclined roof, and of all deviation from those shades of different developments, which impart character to a work of art, generated the monotony, the subject of our complaint. It cannot be denied that in those arts which have nature for their model, the artists of Egypt never sought excellence in true representation. Now architecture is so allied to the other arts, that the principles by which they were guided in these latter were carried through in

the former. It was impossible that the abstract imitation of nature, which constitutes almost the essence of architecture, which is founded upon the most refined observations of the impressions of different objects on our senses, which indicates numberless experiments and successive trials, and which therefore requires the independence of the artist, could be developed in a country where the restrictions of religion and the spirit of routine became the dominant genius of all the arts. In positive imitation, whose existence and principles have been already traced from grottoes and hollowed subterranean apartments, the types of Egyptian architecture were unsusceptible of variety, and very remote from that which characterises invention. The monotony thence resulting was attended by another effect,— that of endeavouring to correct it by a profusion of hieroglyphics. As to the other ornaments employed, they seem to have flowed from caprice, both in selection and employment, resting on no fixed principles of necessity or fitness, nor subject to any laws but those of chance. The original forms, indeed, of Egyptian architecture, unfounded, like those of Greece, on a construction with timber, would not suggest the use of ornament. Nothing seemed fixed, nothing determined by natural types. We must, however, except some of their columns, which do appear to have been formed with some regard to imitation.

89. In the architecture of Egypt we find great want of proportion, or that suitable ratio which the different parts of a body should bear to each other and to the whole. In all organised beings, their parts so correspond, that, if the size of a single part be known, the whole is known. Nature has thus formed them for the sake of dependence on and aid to each other. In works of art, the nearer we approach a similar formation, the more refined and elegant will be its productions. Solidity is abused in the works of the Egyptians; the means employed always seem greater than were necessary. This discovers another cause of their monotony. The masses of material which the country produced measured their efforts and conceptions, and their invention was exhausted by a very restricted number of combinations. Their monuments are doubtless admirable for their grandeur and solidity; but the preponderance of the latter, when carried beyond certain bounds, becomes clumsiness; art then disappears, and character becomes caricature. Though we think it useful thus to analyse Egyptian art, it must not be supposed that we are insensible to its imposing, and often picturesque, effect. It can never be revived, and our observations upon it must be understood as in comparison with Greek art, which has proved so susceptible of modification that it is not likely to be abandoned in any part of the world where civilisation has appeared.

90. Though the private dwellings of the Egyptians were not comparable with their public edifices, they were not altogether devoid of splendour. Examples of them from sculptures may be seen in Mr. Wilkinson's work above quoted. In the towns they of course varied in size and plan. The streets were narrow and laid out with regularity; and the mixture, as frequently met with in eastern towns, of large houses with low hovels, appears to have been avoided. In Thebes, the number of stories were, according to Diodorus, in some cases as much as four and five. Houses of small size were usually connected together, rarely exceeding two stories. They were regular in plan, the rooms usually occupying three sides of a court-yard, separated by a wall from the street; or on each side of a long passage from a similar entrance court. The court was sometimes common to several houses. Large mansions were detached, having often *different entrances on their several sides*, with portals very similar in form to those of their temples. These portals were about 12 or 15 ft. high, and on each side was a smaller door. Entering through the porch, the passage was into an open court wherein was a receiving room for visitors, and this was supported by columns, and closed in the lower part by intercolumnal panels. On the opposite side of the court was another door, by which the receiving room was entered from the interior. Three doors led from this court to another of larger dimensions, ornamented with trees, communicating on the right and left with the interior parts of the building, and having a back entrance. The arrangement of the interior was the same on each side of the court; six or more chambers, whose doors faced each other, opened on a corridor supported by columns on the right and left of the area, which was shaded by a double row of trees. A sitting room was placed at the upper end of one of these areas, opposite the door leading to the great court; and over this and the chambers were the apartments of the upper story. On each side of the sitting-room was a door opening on to the street. Of course there were houses on other plans, which are given by Wilkinson; but the above conveys a sufficient idea of their general distribution. On the tops of the houses were terraces, serving as well for repose as exercise. The walls and ceilings were richly painted, and the latter were formed into compartments with appropriate borders. Some of their villas were on a very large scale, and were laid out with spacious gardens, watered by canals communicating with the Nile.

91. We close this section with a list of the principal ancient edifices of Egypt (for which we are indebted to the work of Mr. Wilkinson), whose situations are marked on the accompanying map (*fig.* 66.). At Heliopolis (*modern name Matarieh*) (No. 1.), a little to the north of Cairo, the obelisk of Osirtasen I., and the remains of walls and houses. Near

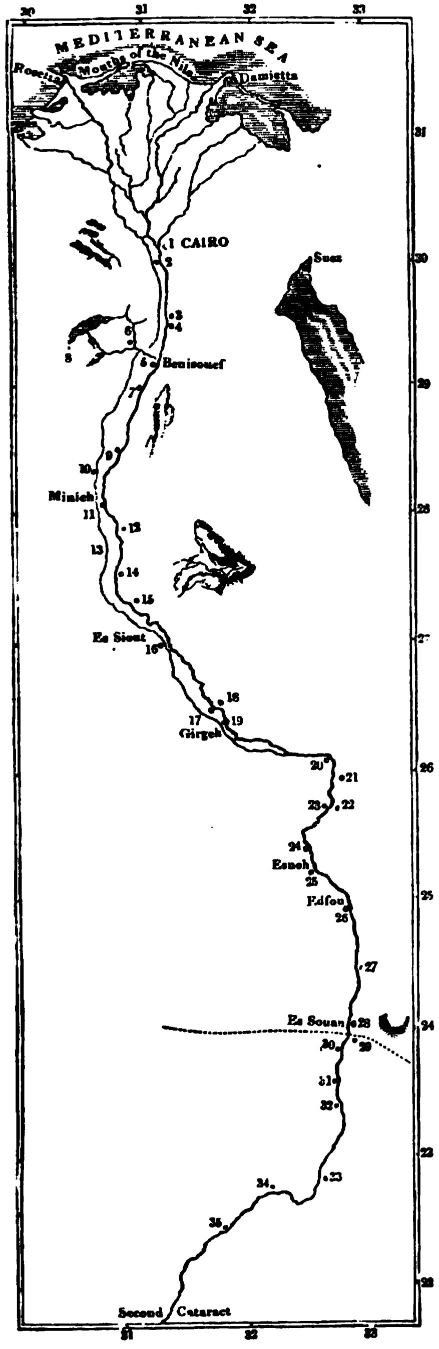


Fig. 66. MAP OF THE NILE.

Cairo, to the south-west, pyramids of Geezeh (No. 2.), Saccara, and Dashoor. At Mitraheni (No. 3.), a colossus of Remeses II.; the mounds of Memphis, fragments of statues, and remains of buildings. About thirty-eight miles above Cairo, on the east bank (No. 4.), are the mounds of Aphroditopolis; and on the opposite bank a false pyramid. Three miles further, on the east bank, the walls of an ancient village called El Heebee (No. 5.), with some hieroglyphics. At Benisooef a road leads to the Fyoom; a brick pyramid at Illahoun (No. 6.), another at El Hawara, and traces of the Labyrinth. An obelisk at Biggig (No. 7.); ruins near Lake Moeris and at Kasr Keroun (No. 8.). From Abou Girgeh (No. 9.), on the west bank, a road to Oxyrinchery (Bahnasa) (No. 10.), where are mounds but no ruins. At Gabel e' Tayr, a rock temple. Eight miles below Minieh (No. 11.) is Acoris (Tehneh), on the east bank, where is a Greek Ptolemaic inscription on the cliff, tombs in the rock with inscriptions on the doors, hieroglyphic tablets, &c. On the east bank, seven miles above Minieh, Kom Ahmar, where are the ruins of an old town and some grottoes. Nine miles further up are the grottoes of Beni Hassan (No. 12.); and about a mile and a half further on a grotto or rock temple of Bubastis or Diana. Antinoe (Shekh Abádeh), west bank, few traces of the town, a theatre, principal streets, baths, &c. Outside the town, the hippodrome. At El Bersheh, a grotto, wherein is a colossus on a sledge. Hermopolis, on the west bank (Oshmounayn) (No. 13.), no remains of it. At Gebel Toona are mummy pits, a tablet of hieroglyphics, and statues in high relief. At Shekh Said (No. 14.) the mountains recede to the eastward, leaving the river; a little beyond is the village of Tel eb Amarna, to the north of which are the remains of a small town, and to the south the ruins of a city, which Mr. W. supposes to have been the Alabastron. To the east are grottoes with sculptures; and on the summit of the mountain an ancient alabaster quarry. At El Hargib (No. 15.), the ruins of an old town. At E' Sioot (No. 16.) (the ancient Lycopolis) are grottoes. At Gow (Antæopolis), a few stones of the temple close to the river. At Shekh Heredee, small grottoes; and a Roman statue at the base of the mountain cut out of a piece of the rock. West of Soohag (No. 17.) is the old town of Athribis, where is a Greek inscription in the ruined temple, and grottoes in the mountain. On the east side of the river, opposite, is E'Khmim (No. 18.) (Parcopolis, Greek inscription of Temple of Pan, and remains of other stone buildings. Mensheeh (No. 19.) (Ptolemais Hermii), on the west bank, from whence three hours' ride to Abydus (now Arabat el Matfoon), where are two temples and many tombs. Hou (Diospolis parva), a few remains of Ptolemaic times. Dendera (No. 20.) (ancient Tentyris) has two temples (*figs.* 67. and 68.), inscriptions, zodiac, &c. At Qoft (Coptos), ruins of the old town and of a temple; and at the village of El Qala, to the north, a small Roman Egyptian temple. Qoos (No. 21.) (Apollinopolis parva) no ruins. At Thebes (No. 22.) (Diospolis magna), on the east bank, Karnac and Luqsor; on the west, tombs of the kings, private tombs, several temples, colossi of the plain, &c. At Erment (No. 23.) (Hermonthis), west bank, a temple and early Christian church. At Tofnees and Asfoon (No. 24.) mounds of ancient towns, but no ruins. Esneh (*fig.* 69.) (Latopolis) (No. 25.) possesses a fine portico, zodiac and quay; sixteen miles from whence is a small stone pyramid. On the east bank, four miles beyond, is El Kab (Eilethyas), where are ruins of a very ancient town; the temples lately destroyed; grottoes in the mountain; and a short distance up the valley three small temples. Edfu (No. 26.) (Apollinopolis magna) has two temples; and eleven miles above it are the remains of an old town. At Komombo (No. 27.) (Ombos) are two temples, and an ancient stone gateway in a crude brick wall on the east side of the inclosure of the temples. At E' Sooan (No. 28.) (Syene), ruins of a small Roman temple, some columns, granite quarries, in one of which is a broken obelisk. Island of Elephanta, opposite the rocks of E' Sooan, is the Nilometer, with Greek incriptions relating to the rise of the Nile. A granite gateway bearing the name of Alexander, son of Alexander the Great. At Philæ (No. 29.) temples and ruins. On the Island of Biggeh, opposite Philæ to the west, ruined temple, tablets, &c.

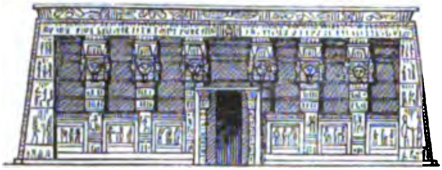


Fig. 67. TEMPLE AT TENTYRIS.

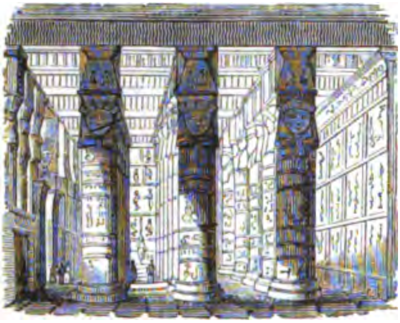


Fig. 68. INTERIOR OF TEMPLE AT TENTYRIS.

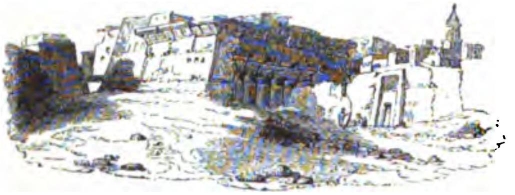


Fig. 69. PORTICO AT ESNEH.

92. In Nubia, temples at Dabode (No. 30.) (Paremboli) and Kababshee (No. 31.) (Talmis); to the north of the last a small but interesting temple, called Bayt el Wellea, cut in the rock, and of the time of Remeses II. A temple at Dandoor (No. 32.), and one cut in the rock, of the time of Remeses II., at Gerf Hossayn (Tutzis). At Sabooa (No. 33.), a temple of the time of Remeses II., with an avenue of sphinxes, the adytum cut in the rock, the rest built. At Assaia (No. 34.) or Amada, a temple of Thothmes ancient; and nearly opposite, on the east bank, is Dayr, where is a temple cut in the rock of the date of Remeses II. At Ypsambool (No. 35.) (*figs.* 70. and 71.), two fine temples

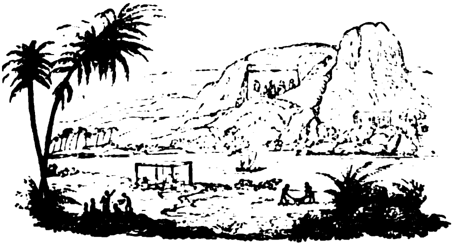


Fig. 70. TEMPLE AT YPSAMBOOL.

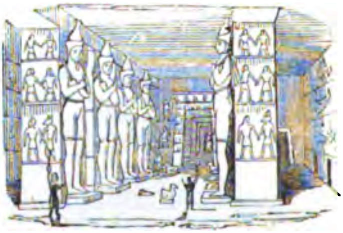


Fig. 71. TEMPLE AT YPSAMBOOL.

cut in the rock of the time of Remeses II., and the finest out of Thebes. Above the last-named place there are no buildings of importance mentioned by our author.

Sect. VIII.

CHINESE ARCHITECTURE.

93. In the first chapter, the reader will remember, we have said that in the tent is to be found the type of this architecture; and one which, M. de Paw justly observes, cannot be mistaken. We are not aware of the utility of a very minute investigation of its style, which in this country is of no further importance than attaches to the silly decoration of gardens with imitations of its productions; but as the object of this work would not be fully attained without some account of it, we propose to consider it, firstly, with respect to its principles, character, and taste; secondly, with respect to its buildings, their parts, and the method of construction adopted in them.

94. (1.) To judge of the arts of a people, we ought to be acquainted with the people themselves, the constitution of their minds, their power, their habits, and the connection of the arts with their wants and pleasures. As one man differs from another, so do these differ among nations. The desire of improving on what has been done before us, no less distinguishes nations than individuals from each other. Whatever may be the cause, this faculty does not seem to be possessed by the Chinese. Unlike their Indian neighbours, amongst whom appears an exuberance of invention, the arts of imitation in China have been bound in the chains of mechanical skill. Their painters are rather naturalists than artists; and an European, engaged on the foreground of a landscape, tells us that the criticism by a native artist on his work was confined to the observation that he had omitted some fibres and sinkings in some of the leaves of the foliage employed in it. The political and moral subjection of the people seems to have doomed them to remain in that confined circle wherein long habit and repugnance to change have enclosed them.

95. In speaking of the principles of Chinese architecture, the word is used in application to those primitive causes which gave birth to it, and which, in every species of architecture, are the elements of its character and the taste it exhibits. The imitation of the tent, as we have before observed, is the true origin of their buildings; and this agrees with our knowledge of the primitive state of the Chinese, who, like all the Tartar tribes, were nomadic. On this is founded the singular construction of their dwellings, which would stand were the walls destroyed; inasmuch as, independent of them, their roofs rest upon timber framing, just as though they had surrounded tents with enclosures of masonry. Indeed, from the accounts of travellers, a Chinese city looks like a large permanent encampment, as well in respect of its roofs as its extent. If, again, we recur to their concave sloped sides, we can arrive at no other conclusion; and though the carpentry of which they are raised has for ages been subjected to these forms, when we consider the natural march of human invention, especially in cases of necessity, we cannot believe that, in a country where the primitive construction was of timber, the coverings of dwellings would at once have been so simple and so light. Their framing seems as though prepared merely for a canvas covering. Again, we have, if more were wanting, another proof, in the posts employed for the support of their roofs. On them we find resting nothing analogous to the architecture for receiving and supporting the upper timbers of the carpentry; on the contrary, the roof projects over and beyond the posts or columns, whose upper extremities are hidden by the eaves; thus superseding the use of a capital. A canvas covering requires but a slender support: hence lightness is a leading feature in the edifices of China. The system of carpentry (if such it can be called) thus induced, will be noticed under the second head; but we must here observe, that lightness is not at all incompatible with essential solidity of construction; and whilst other materials than those which formed tents have been substituted for them, the forms of the original type have been preserved, making this lightness the more singular, inasmuch as the slightest analogy between those of the original and the copy is imperceptible. This change of material prevents in the copy the appearance of solidity, and seems a defect in the style, unless we recur to the type.

96. A characteristic quality of Chinese architecture is gaiety of effect. Their coloured roofs, compared by their poets to the rainbow, — their porticoes, diapered with variegated tints, — the varnish lavished on their buildings, — the keeping of this species of decoration with the light forms of the buildings, — all these unite in producing, to eyes accustomed to contemplate them, a species of pleasure which they would with difficulty relinquish; and it seems reasonable that the architecture of Europe must appear cold and monotonous to men whose pleasure in the arts is more dependent on their senses than on their judgment.

97. Taste in art is a quality of vague signification, except amongst those whose lives are

passed in its practice; neither is this the place to say, upon that subject, more than that, in the application of ornament or decoration to architecture, it must depend on the method of construction. This is not found in that whereof we are writing. With the Chinese, the art of ornamenting a building is an application of capricious finery and patchwork, in which grotesque representations of subjects connected with their mythology often prevail: yet, in this respect, they exhibit a fertility of invention, and produce beautiful abstract combinations quite in character with the general forms. Indeed, the parts of their architecture are in harmony with each other. All is based upon natural principles, and is so adapted to the few and simple wants of a nation whose enormous population alone seems to render it independent of every other people, that no period can be assigned to the future duration of an architecture which, we apprehend, has existed amongst them from the earliest date of their dwelling in cities.

98. (2.) TIMBER is the chief material in use among the Chinese; and that of which the country produces the principal is the *nan-mon*, which, according to some, is a species of cedar; others have placed it among the firs. It is a straight thick tree, and improves with age. De Paw says that it furnishes sticks from twelve to thirteen feet high, of useful wood; but Chambers limits it to a smaller size. Respecting its beauty and duration, all travellers agree. Davis (*Description of the Empire of China*) says that the nan-mo is a description of cedar, which resists insects and lime, and appears to be exclusively used for imperial dwellings and temples. It was an article of impeachment against the minister of Kien-loong, that he had presumed to use this wood in the construction of his private palace. According to Du Halde, the iron-wood, *the-ly-mow*, is as tall as the oaks of Europe, but is less in its trunk, and differs from it in colour, which is darker, and in weight. The author does not tell us whether it is employed for columns. The tse-laû, also called mo-wâng, or king of woods, resembles what we call rosewood; but its use is confined chiefly to articles of furniture. The tchou-tse, or bamboo, grows to a great height in China. Though hollow, it is very hard, and capable of bearing great weight. It is employed for scaffolding and sheds of all kinds; and the frame-work of their matted houses for theatrical exhibitions is carried up with bamboos in a few hours. It is in universal use. The missionaries inform us that BRICK has been in use with the nation from the earliest period, and of both species, — burnt and merely dried in the sun. Chambers describes the walls of the houses built of this material as generally eighteen inches thick. He says, the workmen bring up the foundations for three or four courses in solid work; after which, as the walls rise, the bricks are used in the alternate courses as *headers* and *stretchers* on the two faces of them; so that the headers meet, and thus occupy the whole thickness, leaving a void space between the stretchers: they then carry up another course of stretchers, *breaking* the vertical joints. STONE and MARBLE are little employed; not on account of their scarcity, for they are abundant, nor on the score of economy, for they are acquainted with the method of working them, as is proved from their use in public buildings and tombs. Neither can it arise from the difficulty or want of acquaintance with the means of transport; for we find in their gardens immense blocks introduced for the purposes of ornament; and in their marble staircases, the steps, whatever the length, are always in a single piece. The fear of earthquakes, moreover, does not appear to have been a motive for their rejection. That is rather to be found in the climate, which, especially in the southern parts, would, from the great heat and moisture, tend to render their houses unwholesome. In the scaffolding they use for the erection of their buildings, security and simplicity are the principal features; not, however, unmixed with skill. It consists of long poles, so inclined as to make the ascent easy, and is executed without any transverse bearing pieces.

99. The police of architecture among the Chinese is, to an European, a singular feature in its practice; and we cannot refrain from presenting to the reader the curious restrictions imposed upon every class in their several dwellings. Police, indeed, may be said to govern the arts of China. Its laws detail the magnitude and arrangement permitted for the *lon*, or palace of a prince of the first, second, or third degree; for a noble of the imperial family, for a grandee of the empire, for the president of a tribunal, for a mandarin, — for, indeed, all classes. They extend, also, to the regulation of the public buildings of capitals, and other cities, according to their rank in the empire. The richest citizen, unless bearing some office in the state, is compelled to restrict the extent of his house to his exact grade in the country; and whatever form and comfort he may choose to give to the interior, the exterior of his dwelling towards the street must be in every respect consistent with these laws. According to the primitive laws on this subject, the number of courts, the height of the level of the ground floor, the length of the buildings, and the height of the roofs, were in a progressive ratio from the mere bourgeois to the emperor; and the limits of each were exactly defined. The ordinary buildings are only a single story high: the climate seems to discountenance many stories. Though Pekin is in the fortieth degree of north latitude, the police obliges the shopkeepers and manufacturers to sleep in the open air under their penthouses in the hottest part of the summer.

100. The *leon* is a building of several stories. Of this sort are almost all the small palaces

built by the emperors in their pleasure gardens. The taste for this class of building at one period prevailed to such an extent that houses were constructed from 150 ft. to 200 ft. in height, flanked by towers extending to 300 ft. Though the emperors have, generally, abandoned these enormous buildings, they are still occasionally erected. Most houses of the country are so slightly built as to be incapable of bearing more than one story. Indeed, the necessity for making the most of an area by doubling and tripling its capacity, which exists in the capitals of Europe, does not operate in China.

101. The houses of the Chinese are uniform in their appearance. We here annex the plan and elevation of one (*figs.* 72. and 73.); from which it will be seen that a large portion of the area is occupied by courts, passages, and gardens. Sir W. Chambers describes those of the merchants at Canton as being, generally, a long rectangle on the plan, two stories high, and the apartments divided on the ground floor by a wide passage, which extends through the whole length. On the side towards the street the shops are placed, beyond which a quadrangular open vestibule leads to the private apartments, which are distributed on the right and left of the passage. There is a salon, usually about 18 ft. or 20 ft. long, and 20 ft. wide, open towards the vestibule, or with a screen of canework to protect it from the sun and rain. At the back are doors extending from the floor about half way to the ceiling; the superior part being of trellis work, covered with painted gauze, which gives light to the bedroom. The partition walls are not carried higher than the ground story, and are lined with mats to the height of three feet, above which a painted paper is used. The pavement is of differently coloured stone, or marble squares. The doors are generally rectangular, of wood, and varnished or painted with figures. Sometimes the communication between apartments is in the form of an entire circle, which some have compared to the aperture of a bird-cage. The windows are rectangular, and filled in with framework in patterns of squares, parallelograms, polygons, and circles, variously inscribed in or intersecting each other. The railwork to the galleries is similarly ornamented. The compartments of the windows are generally filled in with a transparent oyster shell instead of glass. The upper floor, which occupies the whole breadth of the house, is divided into several large apartments, which are, occasionally, by means of temporary partitions, converted into rooms for visitors, apart from the family. The sleeping rooms for the people connected with the business are over the shops. The roof stands on wooden columns; and its extremities, projecting beyond the walls, are usually decorated with the representation of a dragon.

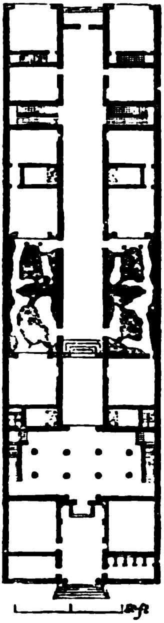


Fig. 72. ground plan.

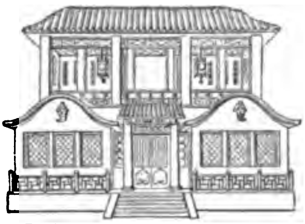


Fig. 73. elevation of a chinese house.

102. In the system of carpentry practised by the Chinese, the columns and beams look more like the bars of a light cage than the supports and ties of a solid piece of framing, or like a collection of bamboos fastened to one another. The accompanying diagram (*fig.* 74.) will convey our meaning to the reader. Their columns vary in their forms and in their proportions from eight to twelve diameters in height, and are without capitals. They are generally of wood, standing on marble or stone bases, and are occasionally polygonal as well as circular. Some are placed on moulded bases.

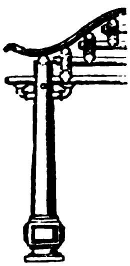


Fig. 74. column and cross-piece.

103. The palaces are constructed on nearly the same plan. Nothing, say the missionaries of Pekin, gives a more impressive idea of a palace and the greatness of its inhabitant, whether we consider its extent, symmetry, elevation, and uniformity, or whether we regard it for the splendour and magnificence of its parts, than the palace of the emperor at Pekin. The whole, they say, produced an effect upon them for which they were not prepared. It occupies an area of upwards of 3600 ft. from east to west, and above 3000 ft. from north to south, without including the three fore-courts. Mr. Barrow, in his *Account of Lord Macartney's Embassy*, describes it as a vast enclosure of a rectangular form, surrounded by double walls, having between them ranges of offices, covered by roofs sloping towards the interior. The included area is occupied by buildings not more than two stories high, and forming several quadrangular courts of various sizes, in the centres of which are buildings standing on granite platforms, 5 ft. or 6 ft. high. These are surrounded by columns of wood, which support a projecting roof turned up at the angles. One of these buildings, serving as a hall of audience, stands like the rest on a platform, and

its projecting roof is supported by a double row of wooden columns, the intervals between which, in each row, are filled with brickwork to the height of 4 ft.; the part above the wall being filled in with lattice work, covered with transparent paper. The courts are intersected by canals spanned by several marble bridges. The gateways of the quadrangles are adorned with marble columns on pedestals, decorated with dragons. The courts contain sculptured lions 7 ft. or 8 ft. high; and at the angles of the building, surrounding each area, are square towers, two stories high, crowned with galleries. The reader will find a delineation of this extraordinary building in Cousin's work, *Du Genie de L'Architecture*, 4to, Paris, 1822, pl. 26. The peristylia of the interior buildings of the palace are built upon a platform of white marble, above which they are raised but a few steps; but this platform is reached by three flights of marble steps, decorated with vases and other ornaments.

104. It is said that there are 10,000 *miao*, or idol temples in Pekin and its environs. Some of these are of considerable size, others are more distinguished for their beauty; there is, however, no sufficient account of them, and we shall therefore proceed to those of Canton, which have been decribed by Chambers. He says that in this city there are a great number of temples, to which Europeans usually apply the name of *pagoda*. Some of these are small, and consist of a single chamber; others stand in a court surrounded by corridors, at the extremity of which the *ting*, or idols, are placed. The most extensive of these pagodas is at *Ho-nang*, in the southern suburb of Conan. Its interior area is of the length of 590 ft., its width 250 ft. This area is surrounded by cells for 200 bonzes, having no light but what is obtained from the doors. The entrance to the quadrangle is by a vestibule in the middle of one of the short sides; and at the angles are buildings 30 ft. square, in which the principal bonzes reside. In the middle of each of the long sides is a rectangular area, surrounded by cells, one containing the kitchens and refectories, and the other, hospitals for animals, and a burying ground. The great quadrangle contains three pagodas or pavilions, each 33 ft. square on the plan. They consist each of two stories, the lowest whereof is surrounded by a peristyle of twenty-four columns. The basement to each is 6 ft. high, to which there is a flight of steps on each side, and the three basements are connected by a broad wall for the purpose of communication between them, with steps descending into the court. The roofs of the peristylia are concave on the exterior; and the angles, which are curved upwards, are decorated with animals. The sides of the upper story are formed with wooden posts, filled in with open framework. Round the foot on the exterior is a balcony with a rail in front. The roof resembles that of the peristyle, and has its angles similarly ornamented. The buildings are all covered with green varnished tiles.

105. The Chinese towers, which also Europeans call pagodas, are very common in the country. The most celebrated, whereof a diagram is presented here (*fig.* 75.), is thus described by P. Le Comte. Its form on the plan is octagonal, and 40 ft. in diameter; so that each side is 15 ft. It is surrounded by a wall at a distance of 15 ft., bearing, at a moderate height, a roof covered with varnished tiles, which seems to rise out of the body of the tower, forming a gallery below. The tower consists of nine stories, each ornamented with a cornice of 3 ft. at the level of the windows, and each with a roof similar to that of the gallery, except that they do not project so much, not being supported by a second wall. They grow smaller as the stories rise. The wall of the ground story is 12 ft. thick, and 8½ ft. high, and is cased with porcelain, whose lustre the rain and dust have much injured in the course of three centuries. The staircase within is small and inconvenient, the risers being extremely high. Each floor is formed by transverse beams, covered with planks forming a chamber, whose ceiling is decorated with painting. The walls are hollowed for numberless niches, containing idols in bas-relief. The whole work is gilt, and seems of marble or wrought stone; but the author thinks it of brick, which the Chinese are extremely skilful in moulding with ornaments thereon. The first story is the highest, but the rest are equal in height. "I counted," says M. Le Comte, "190 steps, of ten full inches each, which make 158 ft. If to this we add the height of the basement, and that of the ninth story, wherein there are no steps, and the covering, we shall find that the whole exceeds a height of 200 ft. The roof is not the least of the beauties which this tower boasts. It consists of a thick mast, whose foot stands on the eighth floor, and rises thirty feet from

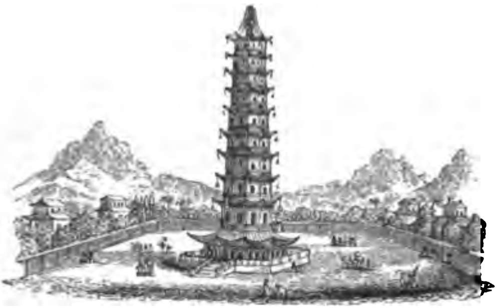


Fig. 75. CHINESE TOWER, OR PAGODA.

the outside of the building. It appears enveloped in a large spiral band of iron, clear by several feet from the pole, on whose apex is a gilt globe of extraordinary dimensions.

106. The word tower has been vaguely applied to all these buildings; but in China there are differences in their application, which are classed under three heads: — 1. *Tai*, or platforms for astronomical or meteorological observations, or for enjoying the air and landscape. 2. *Hou*, such as that just described in detail, being edifices of several stories, isolated and circular, square and polygonal on the plan, built of different materials in different places. 3. *Ta*, which are sepulchral towers. These are commonly massive, of strange but simple forms.

107. The *Pay-leon*, or triumphal arches of the Chinese, are to be found in every city. They are erected to celebrate particular events. Those at *Ning-po* are with a central and two smaller side openings, and are ornamented with polygonal stone columns, supporting an entablature of three or four fasciæ. These are usually without mouldings, the last but one excepted, which is a species of frieze filled with inscriptions. They are crowned with roofs of the usual form, having broad projections, whose angles are turned upwards. The apertures are sometimes square, and sometimes circular headed.

108. China abounds in bridges; but Du Halde and the missionaries have made more of them in their accounts than they appear to deserve. What they have described as a bridge of ninety-one arches between Soo-chow and Hâng-chow, was passed by Lord Macartney, and found to be nothing more than a long causeway. Its highest arch, however, was supposed to be between 20 ft. and 30 ft. high, and its length about half a mile. Some of their bridges, however, as in the case of that observed by the late Sir George Staunton (vol. ii. p. 177.), are skilfully constructed. They have long been acquainted with the use of the arch composed of wedge-shaped voussoirs, perhaps long before it was known in Europe. Their great wall is one of their most remarkable monuments. It consists of an earthen mound, retained on each side by walls of brick and masonry, with a terraced platform of square bricks. Its total height is 20 ft., including a parapet of 5 ft. The thickness at the base is 25 ft., and it diminishes to 15 ft. at the platform. The towers on it, at intervals of about 200 paces, are 40 ft. square at the base, diminishing to 30 ft. at the top; and their height is about 37 ft. Some of the towers, however, are 48 ft. high, and consist of two stories. It extends from the province of Shen-Si to the Wanghay, and in a length of 1500 miles is conducted over mountains, valleys, and rivers, often in places inaccessible to an enemy. (See *fig.* 76.)

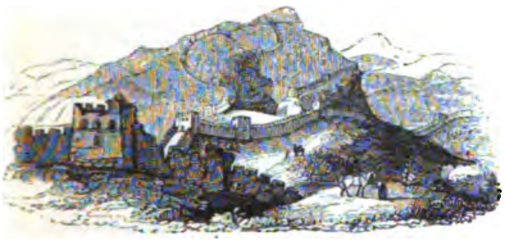


Fig. 76. GREAT WALL OF CHINA.

Sect. IX.

MEXICAN ARCHITECTURE.

109. The architecture of the people who had possession of America before its discovery by Columbus has a considerable claim upon our attention. When a people appears to have had no means of modelling their ideas through study of the existing monuments of older nations, nor of preserving any traces of the style of building practised by the race from which they originated, their works may be expected to possess some novelty in the mode of combination or in the nature of the objects combined; and, in this point of view, American architecture is not without interest. It is, moreover, instructive in pointing out the bent of the human mind when unbiassed by example in the art.

110. North America was found by the Spaniards advanced in agriculture and civilisation, and more especially so in the valleys of Mexico and Oaxaca. These provinces seem to have been traversed by different migratory tribes, who left behind them traces of cultivation. It is not our intention here to discuss the mode of the original peopling of America; but we must, in passing, observe that the vicinity of the continents of Asia and America is such as to induce us to remind the reader that one of the swarms, which we mentioned in the section on Druidical and Celtic Architecture, might have moved in a direction which ultimately brought them to that which, in modern times, has received the name of the New World. The Toultecs appeared in 648, making roads, building cities, and constructing great pyramids, which are yet admired. They knew the use of hieroglyphical paintings,

founded metals, and were able to cut the hardest stone. (*Humboldt, New Spain.*) The Aztecs appeared in 1196, and seem to have had a similar origin and language. Their works, though they attest the infancy of art, bear a striking resemblance to several monuments of the most civilised people. The rigid adherence of the people to the forms, opinions, and customs which habit had rendered familiar to them, is common to all nations under a religious and military despotism.

111. The edifices erected by the Mexicans for religious purposes were solid masses of earth of a pyramidal shape, partly faced with stone. They were called *Teocallis* (Houses of God). That of ancient Mexico, 318 ft. at the base and 121 ft. in height, consisted of five stories; and, when seen at a distance, so truncated was the pyramid that the monument appeared an enormous cube, with small altars covered by wooden cupolas on the top. The place where these cupolas terminated was elevated 177 ft. above the base of the edifice or the pavement of the enclosure. Hence we may observe that the Teocalli was very similar in form to the ancient monument of Babylon, called the Mausoleum of Belus. The pyramids of Teotihuacan (*fig.* 77.), which still remain in the Mexican Valley, have their faces within 52 minutes of a degree of the cardinal points of the compass. Their interior is clay, mixed with small stones. This kernel is covered with a thick wall of porous amygdaloid. Traces are perceived of a bed of lime, which externally covers the stone.

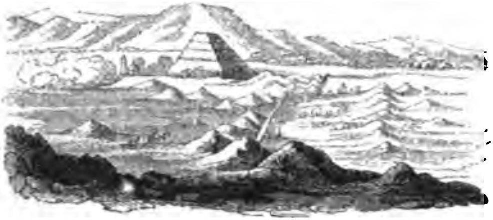


Fig. 77. PYRAMIDS OF TEOTIHUACAN.

112. The great pyramid of Cholula (*fig.* 78.), the largest and most sacred temple in Mexico, appears, at a distance, like a natural conical hill, wooded, and crowned with a small church; on approaching it, its pyramidal form becomes distinct, as well as the four stories whereof it consists, though they are covered with vegetation. Humboldt compares it to a square whose base is four times that of the Place Vendome at Paris covered with bricks to a height twice that of the Louvre. The height of it is 177 ft., and the length of a side of the base 1423 ft.. There is a flight of 120 steps to the platform. Subjoined is a comparative statement of the Egyptian and Mexican pyramids: —

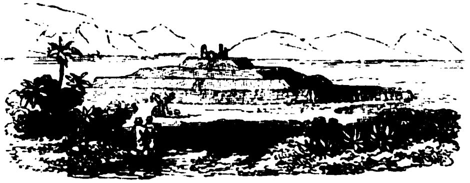


Fig. 78. GREAT PYRAMID OF CHOLULA.

Dimensions.	EGYPTIAN.				MEXICAN.	
	Cheops.	Cephrenes.	Mycerinus.	Saccara (of five stories).	Teotihu-acan.	Cholula.
Height in feet - -	448	398	162	150	171	172
Length of base in feet	728	655	280	210	645	1355

The Cholula pyramid is constructed with unburnt bricks and clay, in alternate layers. As in other *Teocallis*, there are cavities of considerable size, intended for sepulchres. In cutting through one side of it to form the present road from Puebla to Mexico, a square chamber was discovered, built of stones, and supported by beams of cypress wood. Two skeletons were found in it and a number of curiously painted and varnished vases. Humboldt, on an examination of the ruins, observed an arrangement of the bricks for the purpose of diminishing the pressure on the roof, by the *sailing over* of the bricks horizontally. The area on the top contains 3500 square yards, and was occupied by the Temple of Quetzalcoatl, the God of Air, who has yielded his place to the Virgin. By the way, we may here mention that tumuli are found in Virginia, Canada, and Peru, in which there are galleries built of stone communicating with each other by shafts; but these are not surmounted by temples.

113. In the northern part of the intendancy of Vera Cruz, west from the mouth of the Rio Tecolutla, two leagues distant from the great Indian village of Papantla, we meet with a pyramidal edifice of great antiquity. The pyramid of Papantla remained unknown to the first conquerors. It is seated in the middle of a thick forest, and was only discovered by some hunters about thirty-five years ago. It is constructed of immense blocks of stone laid in mortar; but is not so remarkable for its size as for its form and the perfection of its finish, being only 80 ft. square at the base, and not quite 60 ft. high. A flight of fifty-seven

steps leads to the truncated pyramid. Like all the Mexican teocallis, it is composed of stages, six whereof are still distinguishable, and a seventh appears to be concealed by the vegetation with which its sides are covered. The facing of the stories is ornamented with hieroglyphics, in which serpents and crocodiles, carved in relievo, are discernible. Each story contains a great number of square niches symmetrically distributed. In the first story twenty-four are on each side; in the second, twenty; and in the third, sixteen. The number of these niches in the body of the pyramid is 366, and there are twelve in the stairs towards the east.

114. The military intrenchment of Xochiculco, near Tetlama, two leagues south-west of Cuernavaca, is another remarkable ancient monument. It is an insulated hill, 370 ft. high, surrounded with ditches or trenches, and divided by the hand of man into five terraces covered with masonry. The whole has the appearance of a truncated pyramid, whereof the four faces are in the cardinal points of the compass. The masonry is of porphyry, very regularly cut, and adorned with hieroglyphics; among which are to be seen a crocodile spouting up water, and men sitting cross-legged after the Asiatic fashion. On the platform, which is very large, is a small square edifice, which was most probably a temple.

115. Though the province of Oaxaca contains no monuments of ancient Aztec architecture, which astonish by their colossal dimensions, like the houses of the gods of Cholula, Papautla, and Teotihuacan, it possesses the ruins of edifices remarkable for their symmetry and the elegance of their ornaments. The antiquity of them is unknown. In the district of Oaxaca, south of Mexico, stands the palace of *Mitla*, contracted from *Mignitlan*, signifying, in Aztec, the *place of woe*. By the Tzapotec Indians the ruins are called *leoba*, or *luiva* (burial, or tomb), alluding to the excavations found beneath the walls. It is conjectured to have been a palace constructed over the tombs of the kings, for retirement, on the death of a relation. The tombs of Mitla are three edifices, placed symmetrically in a very romantic situation. That in the best preservation, and, at the same time, the principal one, is nearly 130 ft. long. A staircase, formed in a pit, leads to a subterranean apartment, 88 ft. in length, and 26 ft. in width. This, as well as the exterior part of the edifice, is decorated with fret, and other ornaments of similar character (*fig.* 79.). But the most singular feature in these ruins, as compared with other Mexican architecture, was the discovery of six porphyry columns, placed for the support of a ceiling, in the midst of a vast hall. They are almost the only ones which have been found in the new continent, and exhibit strong marks of the infancy of the art, having neither base nor capital. The upper part slightly diminishes. Their total height is 19 ft., in single blocks of porphyry. The ceiling under which they were placed was formed by beams of Savine wood, and three of them are still in good preservation. The roof is of very large slabs. The number of separate buildings was originally five, and they were disposed with great regularity. The gate, whereof some vestiges are still discernible, led to a court 150 ft. square, which, from the rubbish and remains of subterranean apartments, it is supposed was surrounded by four oblong edifices. That on the right is tolerably preserved, the remains of two columns being still in existence. The principal building had a terrace, raised between three and four feet above the level of the court, and serving as a base to the walls it surrounds. In the wall is a niche, with pillars, four or five feet above the level of the floor. The stone lintel, over the principal door of the hall, is in a single block, 12 ft. long and 3 ft. deep. The excavation is reached by a very wide staircase, and is in the form of a cross, supported by columns. The two portions of it, which intersect each other at right angles, are each 82 ft. long by 25 ft. wide. The inner court is surrounded by three small apartments, having no communication with the fourth, which is behind the niche. The interiors of the apartments are decorated with paintings of weapons, sacrifices, and trophies. Of windows there are no traces. Humboldt was struck with the resemblance of some of the ornaments to those on the Etruscan vases of Lower Italy. In the neighbourhood of these ruins are the remains of a large pyramid, and other buildings.

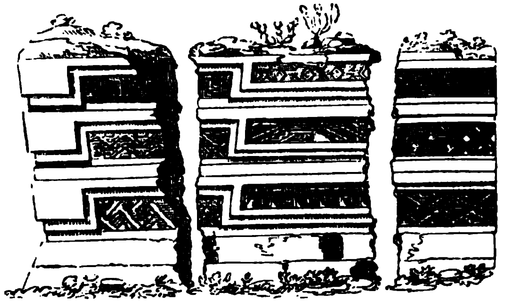


Fig. 79. ORNAMENTS AT THE PALACE OF MITLA.

116. In the intendency of Sonora, which lies north-west of the city of Mexico, and in the Gulf of California, on the banks of the Rio Gila, are some remarkable ruins, known by the name of the *Casa Grande*. They stand in the middle of the vestiges of an ancient Aztec city. The sides are in the direction of the four cardinal points, and are 445 ft. from north

to south, and 276 ft. from east to west. The materials are unburned brick, symmetrically arranged, but unequal in size. The walls are 4 ft. in thickness. The building was of three stories. The principal edifice was surrounded by a wall with towers in it at intervals. From vestiges which appear, it is supposed the town was supplied with the water of the Rio Gila, by an artificial canal. The plain in the neighbourhood is covered with broken earthen pottery painted in white, red, and blue colours.

117. The capital of Mexico, reconstructed by the Spaniards, is undoubtedly one of the finest cities ever built by Europeans in either hemisphere. Perhaps there scarcely exists a city of the same extent which, for the uniform level of the grouud on which it stands, for the regularity and breadth of the streets, and the extent of its great square, can be compared to the capital of New Spain. The architecture is pleasing. Ornament is sparingly applied to it; and the sorts of stone employed, which are a porous amygdaloid called *tetzontli*, and a porphyry of vitreous feld-spath, without any quartz, give to the Mexican buildings an air of solidity, and sometimes even of magnificence. The wooden balconies and galleries which disfigure the European cities in both the Indies are discarded. The balustrades and gates are all of Biscay iron ornamented with bronze; and the houses, instead of roofs, have terraces, like those in Italy and other southern countries. It must, however, be admitted, notwithstanding the progress of the arts there during the last thirty years, that it is less from the grandeur and beauty of the edifices, than from the breadth and straightness of the streets, and their uniform regularity and extent, that Mexico commands the admiration of Europeans.

Sect. X.

ARABIAN, MORESQUE, OR SARACENIC ARCHITECTURE.

118. Before the appearance of Mahomet, in the seventh century, and the consequent establishment of Islamism, the Arabians were by no means celebrated for their skill in architecture. The beautiful country of Happy Yemen, wherein were seated the most ancient and populous of the forty-two cities of Arabia enumerated by Abulfeda, does not appear to have produced what might have been expected from the neighbours of the Egyptians, Syrians, Chaldeans, and Persians. The arts of the surrounding nations seem to have been lost upon them. Though a part of their time and industry was devoted to the management of their cattle, still they were collected into towns, and were employed in the labours of trade and agriculture. The towers of Saana, compared by Abulfeda to Damascus, and the marvellous reservoir of Merab, were constructed by the kings of the Homerites, who, after a sway of two thousand years, became extinguished in 502. The latter, the Meriaba, mentioned by Pliny as having been destroyed by the legions of Augustus, was six miles in circumference, and had not revived in the fourteenth century. "But," says Gibbon, "the profane lustre of these was eclipsed by the prophetic glories of Medina and Mecca." Of the ancient architecture of Arabia there are so few examples remaining, that no satisfactory account can be given of it. Excavations, still seen in rocks, are said to be the houses of the people called Thamud; but the Caaba of Mecca is the only one of the seven temples in which the Arabians worshipped their idols now in existence. It is a quadrangular building, about 36 ft. long, 34 ft. broad, and about 40 ft. high. It is lighted by a door on the east side, and by a window, and the roof is supported by three octangular pillars. Since its adoption by Mahomet, it has been enclosed by the caliphs with a quadrangle, round which are porticoes and apartments for the pilgrims resorting to it. Here were the tombs of the eighty descendants of Mahomet and of his wife; but, in 1803, they were destroyed by the Wahabees, who, however, respected and spared the Caaba and its enclosures.

119. The extraordinary conquests from the Indus to the Nile, under Omar, the second caliph, who, after a reign of ten years, died in A. D. 644, brought the victorious Moslems in contact with nations then much more civilised than themselves. As their empire extended, their love for the arts and sciences increased. The first mosque built out of the limits of Arabia is supposed to be that which was founded by Omar on the site of the ancient temple at Jerusalem. Under the dynasty of the Ommiades, of which race Omar was a member, the cultivation of architecture was carried on with success. The seat of the empire was removed to Damascus, which was considerably enlarged and improved. Among its numerous splendid buildings was the celebrated mosque founded by Alwalid II. It was he who introduced the lofty *minaret*, which, though an innovation at the time, seems, in later years, to have been as necessary a portion of the mosque as the main body of it. This caliph made considerable additions to the mosque at Medina, as he also did to that which had been built by Omar on the site of the Temple of Solomon, above mentioned. His generals and governors of provinces seem to have been equally zealous in the cause of art and the prophet; witness the mosque built by one of the former on taking Samarcand, and

the universal improvement in the provinces under the sway of the latter. Great as were the works just mentioned, the removal of the seat of the empire to the western frontier of Persia, by the second caliph of the dynasty of the Abassides, gave a lustre to Arabian architecture which almost surpasses belief. Almansor, the brother and successor of Saffah, laid the foundations of Bagdad in the year 145 from the Héjira (A. D. 762), a city which remained the imperial seat of his posterity during a period of five hundred years. The chosen spot is on the eastern bank of the Tigris, about fifteen miles above Modain; the double wall was of a circular form; "and such," says Gibbon, "was the rapid increase of a capital, now dwindled to a provincial town, that the funeral of a popular saint might be attended by eight hundred thousand men and sixty thousand women of Bagdad and the adjacent villages." The magnificence displayed in the palace of the caliph could only be exceeded by that of the Persian kings; but the pious and charitable foundation of cisterns and caravanseras along a measured road of seven hundred miles, has never been equalled.

120. About A. D. 660-5, the prudence of the victorious general Akbah had led him to the purpose of founding an Arabian colony in the heart of Africa; and of forming a citadel that might secure, against the accidents of war, the wealth and families of the Saracens. With this view, under the modest title of a caravan station, he planted the colony of Cairoan, in the fiftieth year of the Héjira. "When," observes Gibbon, "the wild beasts and serpents were extirpated, when the forest, or rather wilderness, was cleared, the vestiges of a Roman town were discovered in a sandy plain: the vegetable food of Cairoan is brought from afar; and the scarcity of springs constrains the inhabitants to collect, in cisterns and reservoirs, a precarious supply of rain water. These obstacles were subdued by the industry of Akbah; he traced a circumference of three thousand and six hundred paces, which he encompassed with a brick wall; in the space of five years the governor's palace was surrounded with a sufficient number of private habitations; a spacious mosque was supported by five hundred columns of granite, porphyry, and Numidian marble."

121. "In the West, the Ommiades of Spain," says the same author, "supported with equal pomp the title of Commander of the Faithful. Three miles from Cordova, in honour of his faithful Sultana, the third and greatest of the Abdalrahmans constructed the city, palace, and gardens of Zehra. Twenty-five years, and above three millions sterling, were employed by the founder: his liberal taste invited the artists of Constantinople, the most skilful sculptors and architects of the age; and the buildings were sustained by twelve hundred columns of Spanish and African, of Greek and Italian marble. The hall of audience was incrusted with gold and pearls, and a great bason in the centre was surrounded with the curious and costly figures of birds and quadrupeds." The streets and houses at this place are hollowed out of the rock, which stands 1200 feet above them.

122. Whether we contemplate the materials furnished by Babylon and its neighbourhood, the dismantled towns of Syria, or the abundant ruins of Egypt, and from Tripoli to the Atlantic, it is curious, as the historian of the western Arabs has remarked, to observe that no people constructed, without recourse to the quarry, so many magnificent edifices. In Spain, this was most remarkably the case, whereof the reader will be convinced by reference to Murphy's *Arabian Antiquities*, and Laborde's *Voyage Pittoresque de l'Espagne*.

123. From the latter half of the eighth century to nearly the middle of the ninth, the progress of the Arabians in the sciences was wonderful. Their merit, however, in the art which it is our province to investigate, was of a class inferior to that of the people who invented and carried into execution, though later, the principles which regulated the stupendous monuments of Gothic architecture in Europe. They certainly understood the science of architecture; and works on it were written for the benefit of those whose occupations led them to take an interest in the art.

124. We regret that our limits do not permit us to dwell on the progress in the sciences made by the Arabians, though some of them are intimately connected with our subject. But the information we omit will be much more satisfactorily obtained by the reader consulting the pages of the historian of the decline and fall of the Roman Empire. Our purpose is now to present a concise view of the architecture of the Arabians from Laborde's *Voyage Pittoresque de l'Espagne* (vol. ii. part 1. xliii. et seq.); observing, by the way, that, from our own study of the subject, we are inclined fully to adopt it. In Spain there is a sufficient number of monuments of architecture to class them chronologically, and to assign an epoch to the different styles they exhibit. Though the species does not resemble that which has been denominated Gothic, which is clearly not an imitation, the one and the other sprung from the same source. The point of departure was the architecture of Byzantium, in which city, after the fall of Italy, a totally new style arose, whose development in different modes was the basis of all modern architecture. As though the Coliseum had furnished the hint, the immense edifices, in the style of the period, were constructed with a multiplicity of stories, — they were heavy without, though lightly and richly decorated within; the artists employed in their erection seeming to aim at a transference to the architecture and sculpture on which they were engaged of the oriental profusion of ornament visible in the stuffs of India. This Byzantine school produced the Lombard and

Saxon styles in the North, on which we shall enlarge in the section on Gothic architecture; and, in the South, it produced the Arabian, Saracenic, or Moresque style, by whichever name the reader may choose to distinguish it. Both were strongly impregnated with the vices and defects into which the Roman architecture of the period had fallen. For the sake of illustrating what we mean, we refer, as examples, to the Baths of Dioclesian, to that emperor's palace at Salona, and to the buildings of Justinian and Theodosius,— from all which may be learned the abuses and incongruities which attended the fall, not only of architecture, but of all the other arts. We find in them arches springing from capitals, columns without entablatures, and even zigzag ornaments. But, with all this perversion of taste, the general form of the plans of the edifices altered not: that of the temples more particularly continued unchanged. Some great convulsion was necessary before they could undergo alteration, and such was the introduction of Christianity. Thus, says Saint Isidore, the basilica suffered transformation into the Christian church: — "Basilicæ olim negotiis plenæ, nunc votis pro salute susceptis." Of this, in a succeeding page, we shall have more to say. But the change was not confined to the basilica; the palace and domestic dwelling equally partook of the alteration of wants. The Romans, whilst masters of the world, were careless in protecting their cities by walls. Defence was only necessary on their frontiers; and there, walls and towers were constructed, from which was the first hint for the castle, of which the Roman villa, *fortified*, is the type. When, however, Italy was invaded, the fate of war soon caused exterior decoration to be sacrificed to internal comfort and luxury; and even Rome, under Belisarius, was surrounded by walls and towers. The people, whose prowess made these precautions necessary, soon found the convenience of adopting similar habits and buildings.

125. The Arabians, whose wandering life could scarcely be imagined capable of such a change, ultimately established themselves in Roman castles, and turned the Christian churches, which, at the period, were extremely numerous, into mosques. For some time, the architecture of the Goths, of the Arabians or Moors, was, as respects plan, the same; not less so was the character of the ornaments employed by both nations; but it was not long before these diverged into styles which possessed each its peculiar beauties. The Christians soon used the pointed arch; and the style they adopted became slender and tall, whilst that of the Moslems, from the nature of the climate and their peculiar habits, was deficient in elevation, though in the end it acquired a lightness and elegance which it did not at its origin possess. But it is proper, here, to impress on the mind of the reader that Gothic and Arabian architecture have nothing in common between them, except their origin from a common source. It is an error to confound them, or to suppose that the pointed arch is found in any strictly Arabian edifices. That, as far as we can ascertain, did not exist before the eleventh century. It seems to have been a development in the parts of a style which, as it passed into more northern latitudes, became more acute in the roofs, from the necessity of discharging the rain and snow with greater facility. This pointed style spread itself over some parts of India; but, there, none of the examples are older than the fourteenth or fifteenth century. Except in ornamental detail, whereof we append two specimens (*figs.* 80, 81.) from the Alhambra, the Arabs were not inventive. It is not

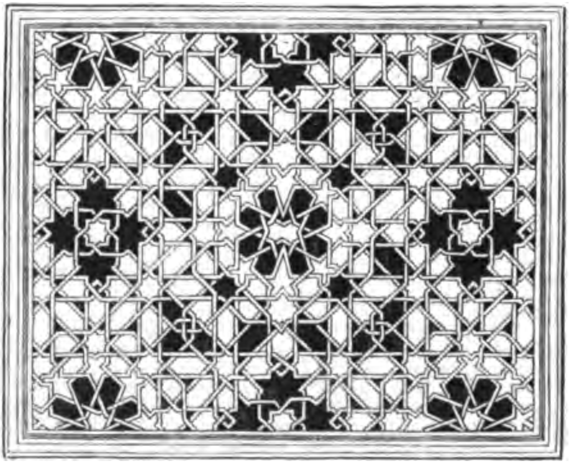


Fig. 80. PAVEMENT, ALHAMBRA.

unlikely that their skill in geometry greatly assisted them in the extraordinary combination of lines to be found in their decorations, which nothing can surpass; nor was it till the time of the Abassides that the Arabians became fully acquainted with what had been done by the Greeks. This knowledge was not confined to them, for there is abundant proof, 1. That all the modern arts, as well of the North, as of the West and South, had their origin from the Greek empire at Constantinople, which at that period gave the fashion in them, as did Italy five centuries afterwards. 2. That the plans of churches and mosques are traceable to that of the ancient basilica, as in the citadels of the middle ages, and the palaces of the Greek emperors, are to be found the types of the Gothic castle and of the Moresque alcazar. 3. That the Gothic and Saracenic styles attained their several perfection in very different manners as to the details of their distribution and ornament, and acquired peculiar characters, which in both may be divided into three periods, the last in each being lost in the change that took place in Italy on the revival of the arts. The periods of the Gothic will be noticed under the proper section.

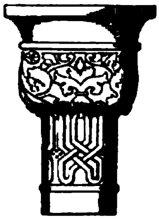


Fig. 81. CAPITAL, ALHAMBRA.

126. The *first period* in the history of Moresque architecture is from the foundation of Islamism to the ninth century, of which the finest example was the Mosque of Cordova in Spain. This was commenced in 770 by Abderahman, and finished by his son and successor, Hisham. Its plan is a parallelogram, whose longest side is 620 ft. by 440, formed by a wall and counterforts, both of which are embattled. The height of the wall varies from 35 to 60 ft., and its thickness is 8 ft. The whole of the quadrangular space is internally divided into two parts, viz. a court of 210 ft. in depth, the mosque itself covering the remainder of the area. The mosque consists of nineteen naves (of a portion of one whereof *fig.* 82. is a diagram) formed by seventeen ranks of columns from south to north, and thirty-two narrower naves from east to west. Each of these naves is about 16 ft. wide from north to south, and about 400 ft. long, their width in the opposite direction being less. Thus the intersection of the naves with each other produces 850 columns, which, with fifty-two columns in the court, form a total of upwards of 900 columns. They are about 18 in. in diameter, the mean height of them is about 15 ft., and they are covered with a species of Corinthian and Composite capital, of which there are many varieties. The columns have neither socle nor base, and are connected by arches from one to another. The ceilings are of wood, painted, each range forming, on the outside, a small roof, separated from those adjoining by a gutter. The variety of the marbles of the columns produces an effect of richness which all agree is very striking. They were most probably procured from the Roman ruins of the city. It is impossible to pass over the description of this mosque without calling to mind the resemblance it bears in its arrangement to the basilicas at Rome. The reader who has seen St. Agnese and St. Paolo fuori le mura, we are sure, will think with us. After the conquest of Cordova in 1236, this mosque was converted into a cathedral. In 1528, it was much disfigured by modern erections, which were necessary for better adapting it to the service of the Christian religion. These, however, have not so far ruined its ancient effect as to prevent an idea being formed of it when in its splendour. The decorations throughout are in stucco, painted of various colours, decorated with legends, and occasionally gilt like the churches of the Lower Empire.

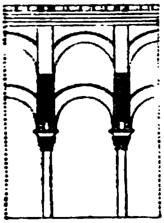


Fig. 82. MOSQUE AT CORDOVA.

127. In the *second period*, the style greatly improved in elegance. It lasted till the close of the thirteenth century, just before which time was founded the royal palace and fortress of the Alhambra, at Granada (*fig.* 83.), perhaps the most perfect model of pure Arabian architecture that has existed. During this period, no traces of the Byzantine style are to be found. An exuberance of well-tempered ornament is seen in their edifices, whose distribution and luxury manifest the highest degree of refinement. Speaking of the interior of the building above mentioned, M. de Laborde says, that it exhibits "tout ce que la volupté, la grâce, l'industrie peuvent reunir de plus agréable et de plus parfait." After passing the principal entrance, you arrive at two oblong courts; one whereof, celebrated in Arabian history, called the Court of the Lions, is in *fig.* 84. represented on the following page. This court is 100 ft. long and 50 ft. broad, having 128 columns of white marble. Round these two courts, on the ground floor, are disposed the apartments of the palace. Those for state look out towards the country; the rest, cooler and more retired, have openings for light under the interior porticoes. The whole is on one plane, the walls being placed so as exactly to suit the plateau of the rock; its entire length is about 2300 ft., and breadth 600 ft. The doors are few and large, and the windows, except on the side where the landscape is most magnificent, are chiefly towards the interior. In one of the apartments, the Arabian architect has, in an inscription, given his reason for this adoption, in the following terms: — "My windows admit the light, and exclude the view of external objects, lest the beauties of

nature should divert your attention from the beauties of my work." The walls are covered with arabesques, apparently cast in moulds, and afterwards joined together. The ornaments are in colours of gold, pink, light blue, and a dusky purple, the first colour being nearest the eye, and the last furthest from it; the general surface, however, is white. The walls, to the height of four feet, were lined with variously figured and coloured porcelain mosaics, as were the floors. The Arabs of the Spanish caliphate appear to have known some mode of preventing the decay of paint and timber, for the paintings, in which the medium for the colour is not oil, retain the original freshness of their colours, and the woodwork of the ceilings presents no symptoms of decomposition. It has been conjectured that the soundness of the wood throughout has arisen from the trees being lanced or drained of their sap at the time of felling; but it may be, that the coating of paint has had some effect in producing the result. Description conveys no notion of this extraordinary edifice: the reader who wishes to obtain one must refer to Murphy's work, already mentioned.

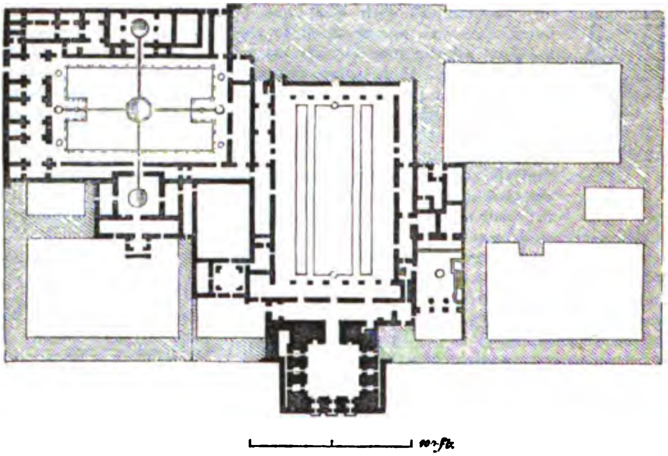


Fig. 83. PLAN OF THE ALHAMBRA.

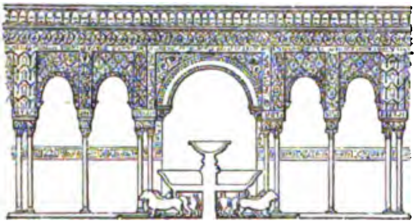


Fig. 84. COURT OF THE LIONS, ALHAMBRA.

128. The *third period* of Arabian architecture is from the end of the thirteenth century to the decline of the Saracen power in Spain. During a portion of this period, it was used by the Spaniards themselves, and like the Gothic, in the northern and middle parts of Europe, was engrafted on the style which crept from Italy into all countries till the Renaissance. During this period were built the castles of Benavento, Penafiel, and Tordesillas; and the alcazars of Segovia and Seville. The plans continued much the same; but Greek ornaments began to appear, with Moresque arches on Corinthian columns. At this time, also, representations of the human figure are to be seen, which, by the laws of Mahomet, were strictly forbidden. There was a charm about this architecture which makes one almost regret that reason and advance in civilisation have extinguished it.

129. We are not to look to the works of the Arabians for the real grandeur which is exhibited in the works of Egypt, Greece, or Rome. Brick was the material most used. When stone was employed, it was covered with a coating of stucco. In their constructive combinations there is nothing to surprise. The domes which crown their apartments are neither lofty nor large in diameter, neither do they exhibit extraordinary mechanical skill. The Arabian architects seem to have been unacquainted with the science of raising vaults on lofty piers. In the specimen cited at Cordova, the span, from pier to pier is less than 20 ft., which would not have required much skill to vault, yet we find the ceilings of timber. The use of orders was unknown to them; the antique columns which they introduced were employed as they found them, or imitations of them, without an acquaintance with the types from which they were derived, with their principles or proportions. In truth,

their columns are posts. We do not find, in the forms of Arabian art, that character of originality which can be traced from local causes. The Arabians had spread themselves out in every direction, far from their own country, in which they had never cultivated the arts; hence their architecture was founded upon the models before them, which the Byzantine school supplied. Of the forms of their arches, some whereof are here exhibited (*fig.* 85.), the most favourite seems to have been the horse-shoe form. They may be ranged into two classes, — that just named, and the other, that wherein the curve is of contrary flexure, and described from several centres. Both classes are vicious in respect of construction, from the impossibility of gaining resistance to thrust at the abutments. In masonry, such arches could not be executed on a large scale. In brick arches, however, the surface of the cement is so increased, that if it be good, and great care be used in not removing the centres till the cement is set, great variety of form in them may be hazarded. If the pleasure — perhaps we may say sensuality — of the eye is alone to be consulted, the Arabians have surpassed all other nations in their architecture. The exquisite lines on which their decorations are based, the fantasticness of their forms, to which colour was most tastefully superadded, are highly seductive. Their works have the air of fairy enchantment, and are only to be compared to that imagination with which the oriental poetry abounds. The variety and profusion wherewith they employed ornament impart to the interior masses of their apartments the appearance of a congeries of painting, incrustation, mosaic, gilding, and foliage; and this was probably much augmented by the Mahometan law, which excluded the representation of the human figure. If a reason be unnecessary for the admission of ornament, nothing could be more satisfactory than the splendour and brilliancy that resulted from their combinations. One of their practices, that of introducing light into their apartments by means of openings in the form of stars, has a magical effect.

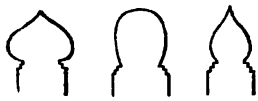


Fig. 85. ARABIAN ARCHES.

130. We have principally confined ourselves, in the foregoing remarks, to the architecture of the Arabians as it is found in Spain, which, it is proper to observe, is only a class of the edifices in the style. There is so close a resemblance between the buildings of that country and those of other places that were, and still are, under the dominion of the Moors, that, allowing only for difference of climate, we might have left the subject without further illustration, but that we think the representation in *figs.* 86. and 87. of a Turkish house at Algiers, which we have extracted from Durand's *Parallèle des Edifices*, may give a better idea of Arabian architecture than a host of words.

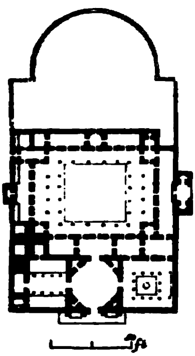


Fig. 86. PLAN, HOUSE AT ALGIERS.

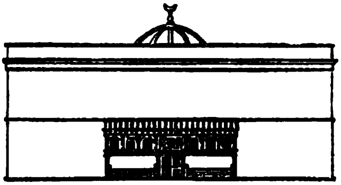


Fig. 87. ELEVATION, HOUSE AT ALGIERS.

131. In *Mecca*, the city of the Prophet, the houses are of stone, and three or four stories in height. The material employed indicates solidity of construction. The streets are regular. The leading features are — the balconies covered with blinds; fronts of the houses much ornamented; doors, with steps and small seats on both sides; roofs terraced, with very high parapets, opened at intervals by a railing formed of brick, in which holes are left for the circulation of the air, at the same time giving an ornamental appearance to the front; staircases narrow and inconvenient; rooms of good dimensions and well-proportioned, having, besides the principal windows, an upper tier. *Damascus*, of which a slight view (*fig.* 88.) is annexed, has been described as resembling a large camp of conical tents, which, on a nearer approach, are found to be small cupolas to the houses. Brick, sun-dried, is the principal material, and the forms of the roofs mentioned are absolutely necessary to protect against the winter rains. Streets generally narrow, houses well supplied with fountains, and containing a large number of houses that may be ranked as palaces. Mosques, many in number, but presenting none that are very remarkable. The bazaars and baths of considerable size and splendour. In *Bagdad*, there are many large squares. The gates erected by the caliphs are still in existence, and are fine specimens of Arabian art. Its walls of mud are 25 ft. in height, but within them are ramparts, carried on arches. In *Bussorah*, the most remarkable feature is the mode in which they construct their arches, which is effected without centres.

132. We do not think it necessary to detain the reader on the architecture of Moorish or Western Arabia. As in the eastern parts of the ancient empire, the houses usually consist of a court, whereof some or all of its sides are surrounded by galleries. Narrow rooms run generally parallel with the gallery, usually without any opening but the door

opening on to the gallery. Roofs are flat or terraced. Walls variously built, often of lime, plaster, and stones, carried up in a sort of casing, which is removed when the work is set.

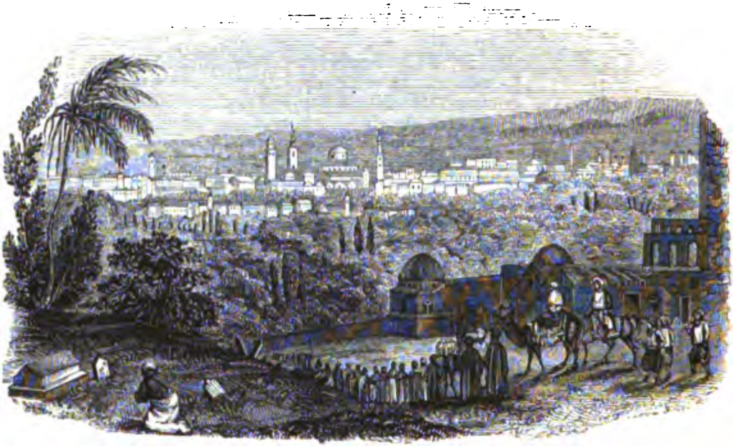


Fig. 88. VIEW OF DAMASCUS.

From want of good timber, the rooms are narrow. The mosques are by no means worthy of notice. *Fez*, an ancient Arabian city, contains some lofty and spacious houses. Its streets are narrow, and on their first floors have projections which much interrupt the light. In the centre of each house is an open quadrangle, surrounded by a gallery, communicating with a staircase. Into this gallery the doors of the apartments open. The ceilings are lofty, the floors of brick. All the principal houses are supplied with cisterns in the lower parts, for furnishing a supply to the baths, a luxury with which also every mosque is provided. In this town there are nearly two hundred caravanseras or inns, three stories high, in each of whose apartments, varying from fifty to one hundred, water is laid on for ablution. The shops, as in Cairo, are very small; so much so, that the owner can reach all the articles he deals in without changing his posture. In *Tripoli*, the houses rarely exceed one story in height; but we must be content with observing that the character is still the same. "Nec facies omnibus una, nec diversa tamen." Though the late Sultan built a new palace in the Italian style at Constantinople, the Moslems will not easily relinquish a style intimately allied to their habits and religion, a style whereof *fig.* 89. will convey some idea to the reader. He is also referred to *figs.* 31, 32, and 33., as examples of the same style in Persia.

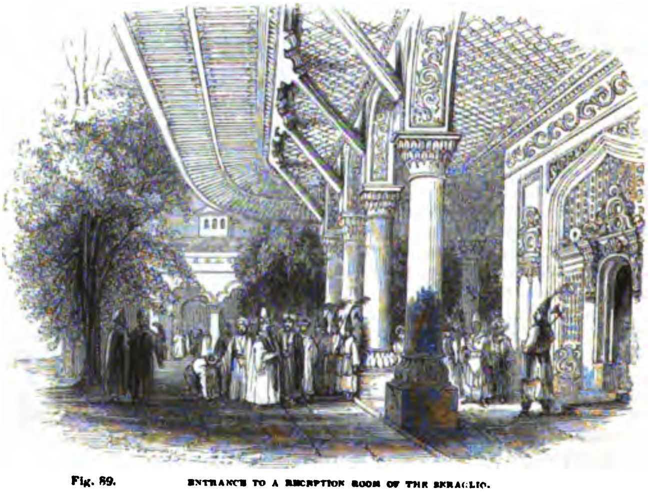


Fig. 89. ENTRANCE TO A RECEPTION ROOM OF THE SERAGLIO.

Sect. XI.

GRECIAN ARCHITECTURE.

133. The architecture of Greece is identical with columnar architecture. Writers on the subject have so invariably treated the hut as the type on which it is formed, that, though we are not thoroughly satisfied of the theory being correct, it would be difficult to wander from the path they have trodden. In the section on Egyptian architecture, we have alluded to the tombs at Beni-hassan, and we here present a representation of a portion of them from a sketch with which we were favoured many years since by Mr. Charles Barry (*fig.* 90.). The reader will, in it, be struck by the appearance of the Doric column, almost in its purity. Wilkinson (*Manners and Customs of the Ancient Egyptians*) is of opinion that the date of these tombs is 1740 B. C., that is, in the time of the first Osirtasen, an antiquity which can be assigned to no example in Greece. These tombs are excavated in a rock, a short distance from the Nile, on its right bank, about forty-eight French leagues south of Cairo. Two of them have architectural fronts like the above plate. The columns are five diameters and a half in height. The number of the flutes, which are shallow, is 20, and the capital consists of a simple abacus. There are no indications of a base or plinth. Above the architrave, which is plain, there is a projecting ledge of the rock, somewhat resembling a cornice, whose soffit is sculptured, apparently in imitation of a series of reeds, laid transversely and horizontally. There certainly does, in this, appear some reference to imitation of a hut, and the refinement of the Greeks, in after ages, may have so extended the analogy as in the end to account for all parts of the entablature. The tradition doubtless existed long before Vitruvius wrote, who gives us nothing more than the belief of the architects of his time. The point is not, at this time, likely to be answered satisfactorily; if it could, it might be important, as leading to the solution of some points of detail, which limit the propriety or impropriety of certain forms in particular situations. Having thus cautioned the reader against implicit faith in the system we are about to develope, we shall preface it by the opinion, on this subject, of M. Quatremère de Quincy, an authority of great value in everything that relates to the art. Carpentry, says that writer, is incontestably the model upon which Greek architecture is founded; and of the three models which nature has supplied to the art, this is, beyond doubt, the finest and most perfect of all. And again, he observes, whoever bestows his attention on the subject, will easily perceive that, by the nature of it, it includes all those parts that are effective for utility and beauty, and that the simplest wooden hut has in it the germ of the most magnificent palace.

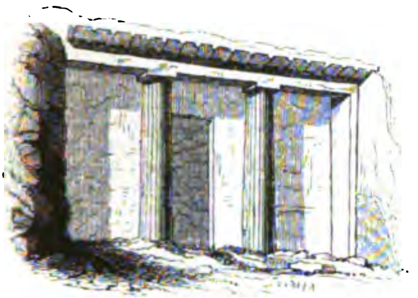


Fig. 90. TOMB AT BENI-HASSAN.

134. We must here premise that this section is strictly confined to the architecture of Greece and its colonies. Much confusion has arisen from the want of strict limits to the term *Grecian Architecture*, one which has been indiscriminately applied to all buildings in which the orders appear. The orders were altered in their profiles, proportions, and details by the Romans; and though between them and those of the Greeks there is a general resemblance, and their members are generally similar, yet, on a minute examination, great difference will be found. In the former, for instance, the contour of every moulding is a portion of a circle; in the latter, the contours of the mouldings are portions of conic sections. In Roman architecture, we find the dome, which in Greek architecture never occurs. In the latter, the arch is never seen; in the former, it is often an important feature. Indeed, the columnar style, as used by the Greeks, rendered arches unnecessary; hence, in all imitation of that style, its introduction produces a discord which no skill can render agreeable to the educated eye. Attempts have been made by the modern German architects to introduce the use of the arch with Greek forms; but they have been all signal failures, and that because it is incapable of amalgamation with the solemn majesty and purity of Greek composition. Before such blending can be accomplished with success, the nature of pure Greek architecture must be changed.

135. Following, then, the authors, ancient and modern, on the origin of the art, we now proceed to a development of its origin. The first trees or posts which were fixed in the earth for supporting a cover against the elements, were the origin of the isolated columns which afterwards became the supports of porticoes in temples. Diminishing in diameter

as they rose in height, the tree indicated the diminution of the column. No type, however, of base or pedestal is found in trees: hence the ancient Doric is without base. This practice, however, from the premature decay of wood standing immediately on the ground, caused the intervention of a step to receive it, and to protect the lower surface from the damp. Scamozzi imagines that the mouldings at the bases and capitals of columns had their origin in cinctures of iron, to prevent the splitting of the timber from the superincumbent weight. Others, however, are of opinion that the former were used merely to elevate the shafts above the dampness of the earth, and thereby prevent rot. In the capital, it seems natural that its upper surface should be increased as much as possible, in order to procure a greater area for the reception of the architrave. This member, or chief beam, whose name bespeaks its origin, was placed horizontally on the tops of the columns, being destined, in effect, to carry the covering of the entire building. Upon the architrave lay the joists of the ceiling, their height being occupied by the member which is called the frieze. In the Doric order, the ends of these joists were called triglyphs, from their being sculptured with two whole and two half glyphs or channels. These, however, in the other orders in strictly Greek architecture, do not appear in the imitation of the type, though in Roman architecture it is sometimes otherwise, as in the Composite order of the Coliseum at Rome, where they are sculptured into consoles. The space between the triglyphs was, at an early period of the art, left open, as we learn from a passage in the Iphigenia of Euripides, where Pylades advises Orestes to slip through one of the metopæ, in order to gain admission into the temple. In after times, these intervals were filled up, and in the other orders they altogether disappear, the whole length of the frieze becoming one plain surface. The inclined rafters of the roof projected over the faces of the walls of the building, so as to deliver the rain clear of them. Their ends were the origin of the mutule or modillion, whereof the former had its under side inclined, as, among many other examples, in the Parthenon at Athens. The elevation, or as it is technically termed, pitch of the pediment, followed from the inclined sides of the roof, whose inclination depended on the nature of the climate. Thus authors trace from the hut the origin of the different members of architecture which a consideration of the annexed diagram will make more intelligible to the reader. *Figs.* 91. and 92. exhibit the parts of a roof in elevation and section: a a are the architraves or *trabes;* b b the ridge piece or *column;* c the king-post or *columna* of a roof; d d the tie-beam or *transtrum;* e the strut or *capreolus;* f f the rafters or *cantherii;* g g g g the purlines or *templa;* h h the common rafters or *asseres.* The form of the pediment became an object of so much admiration, and so essential a part of the temple, that Cicero says, if a temple were to be built in heaven, where no rain falls, it would be necessary to bestow one upon it. "Capitolii fastigium illud, et cæterarum ædium, non venustas sed necessitas ipsa fabricata est. Nam cum esset habita ratio quemadmodum ex utraque parte tecti aqua delaberetur utilitatem templi fastigii dignitas consecuta est, ut etiam si in cœlo capitolium statueretur ubi imber esse non potest, nullam sine fastigio dignitatem habiturum fuisse videatur." (*De Oratione*, lib. iii.) The inclination of the pediment will be hereafter discussed, when we speak on the article Roof, in another part of the work. Under the section on Cyclopean Architecture, mention has been made of the works at Tiryns and Mycene. We do not think there is sufficient chain of evidence to connect those ruins with the later Grecian works, though it must be confessed that the temples of Sicily, especially at Selinus, and perhaps those at Pæstum, are connecting links. Perhaps the sculptures at Selinus might be properly called Cyclopean sculpture, in its more refined state.

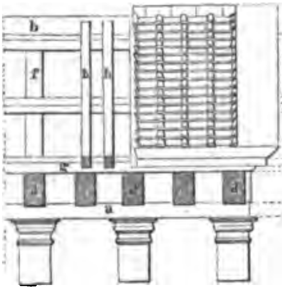


Fig. 91. ELEVATION.

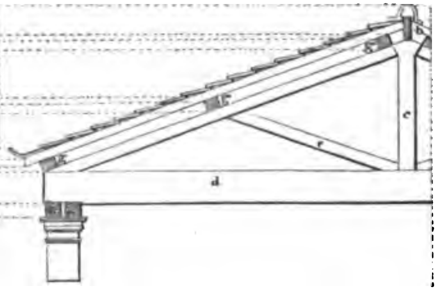


Fig. 92. SECTION.

136. Architecture, as well as all the other arts, could only be carried to perfection by slow steps. Stone could not have been used in building until the mechanical arts had been well known. It is curious that Pliny gives the Greeks credit only for caves as their original dwellings, from which they advanced to simple huts, built of earth and clay. His words are (lib. vii. s. 57.), "Laterarias ac domos constituerunt primi Euryalus et Hyperbias

fratres Athenis: antea specus erant pro domibus." This, perhaps, is no more than a traditionary fable. Fables of this kind, however, often have some foundation in fact. We are not always inclined to discard them, for we have little more than tradition for the early excellence of the Athenians in civilisation, a nation among the Greeks who first became a body politic, and whose vanity caused them to assume the name of *Αυτοχθονες*, from a belief, almost sanctioned by Plato, that their ancestors actually rose from the earth. How strong the prevailing opinion was of the original superiority of the Athenians, may be gathered from Cicero, in his oration for Flaccus. "Adsunt," he says, "Athenienses, unde humanitas, doctrina, religio, fruges, jura, leges ortæ, atque in omnes terras distributæ putantur: de quorum urbis possessione, propter pulchritudinem, etiam inter deos certamen fuisse proditum est: quæ vetustate eà est, ut ipsa ex sese suos cives genuisse dicatur." But we shall not attempt, here, an early history of Greece; for which this is not the place, and, if accomplished, would little answer our views. The Greeks exhibited but little skill in their earliest edifices. The temple of Delphi, mentioned by Homer, in the first book of the Iliad (v. 404. et seq.), which Bryant supposes to have been originally founded by Egyptians, was, as we learn from Pausanias (*Phocic.* c. 5.), a mere hut, covered with laurel branches. Even the celebrated Areopagus was but a sorry structure, as we learn from Vitruvius (lib. ii. cap. 1.), who judged of it from its ruins. The fabulous Cadmus — for we cannot help following Jacob Bryant in his conjectures upon this personage — has been supposed to have existed about 1519 B. C., to have instructed the Greeks in the worship of the Egyptian and Phœnician deities, and to have taught them various useful arts; but this carries us so far back, that we should be retracing our steps into Cyclopean architecture, if we were here to dwell on the period; and we must leave the reader — as is our own, and as we apprehend will be the case with all who may succeed us — to grope his way out of the darkness as best he may.

137. The earliest writer from whom gleanings can be made to elucidate the architecture of Greece is the father of poets. To Homer we are obliged to recur, little as we approve of the architectural graphic flights in which the poet is wont generally to indulge. Though the Odyssey may not be of so high antiquity as the Iliad, it is, from internal evidence, of great age, for the poem exhibits a government strictly patriarchal, and it sufficiently proves that the chief buildings of the period were the palaces of princes. We may here, in passing, observe, that in Greece, previous to Homer and Hesiod, the sculptor's art appears to have been unknown, neither was practised the representation of Gods. The words of Athenagoras (*Leg. pro Christ.* xiv.) are — *Αἱ δ' εικονες μεχρι μηπω πλαστιχη, και γραφικη, και ανδριαντοποιητικη ησαν, ουδε ενομιζοντο.* The altar, which was merely a structure for sacred use, was nothing more than a hearth, whereon the victim was prepared for the meal; and it was not till long after Homer's time that a regular priesthood appeared in Greece. In Sparta, the kings performed the office. In Egypt, the dignity was obtained by inheritance; as was the case in other places. The Odyssey places the altar in the king's palace; and we may reasonably assume that the spot was occasionally, perhaps always, used as the temple. From such premises, it is reasonable to conjecture that until the sacerdotal was separated from the kingly office, the temple, either in Greece or elsewhere, had no existence. It may not be without interest to collect, here, the different passages in the Odyssey, which bear upon the nature and construction of the very earliest buildings of importance. Between the *αυλη* and the *δομος* there must have been a distinction. The former, from its etymology *αω*, must have been a *locus subdialis;* and though it is sometimes used (*Iliad*, Z. 247.) for the whole palace, such is not generally its meaning in the Odyssey. The *αυλη* was the place in which the female attendants of Penelope were slain by Telemachus (*Odyss.* X. 446.), by tying them up with a rope over the *ϑολος* or ceiling. Hence we arrive at the conclusion that this *ϑολος* belonged to the *αιθουσα* or cloister, supposing, as we have done, that the *αυλη* was open at top, and the *αιθουσα* is described (*Iliad*, Υ. 176.) as *εριδουπος*, that is, sonorous or echoing, and as circumscribing the open part of the *αυλη*. The *ϑολος* was supported by *κιονες*, posts or columns, and in the centre of the *αυλη* stood the *βωμος* or altar. If our interpretation be correct, the *μεσοδμαι* in this arrangement must be the spaces between the columns or posts, or the intercolumniations, as the word is usually translated; and the passage in the Odyssey (T. 170.), wherein Telemachus is said to have seen the light on the walls, becomes quite clear. The passage is as follows: —

> *Εμπης μοι τοιχοι μεγαρων, καλαι τε μεσοδμαι,*
> *Εἰλατιναι τε δοκοι, και κιονες υψοσ' εχοντες,*
> *Φαινοντ' οφθαλμοις.*

There seems no doubt that the word *αιθουσα* will bear the interpretation given, and the arrangement is nothing more than that of the hypæthral, and even correspondent with the Egyptian temple, particularly that of the temple at Edfou, described by Denon, and represented in his plate 34.

138. Before we quit this part of our subject, let us consider the description which Homer (*Odyss.* H. 81.) gives of the house of Alcinous as illustrative of Greek architecture. This dwelling, which Ulysses visited, had a brazen threshold, *ουδος*. It was *υψερεφης* or

lofty-roofed. The walls were brazen on every side, from the threshold to the innermost part. This, however, is rather poetic. The coping ϑριγκος was of a blue colour. The interior doors are described as gold. The jambs of them, *σταθμοι*, were of silver on a brazen threshold. The lintel *υπερθυριον* was silver, and the cornice *κορονη* of gold. Statues of dogs, in gold and silver, which had been curiously contrived by Vulcan himself, guarded the portal. Thus far, making all due allowance for the poet's fancy, we gain an insight into what was considered the value of art in his day, more dependent, it would seem, on material than on form. Seats seemed to have been placed round the interior part of the house, on which seats were cushions, which the women wrought. But we must return to the construction of the *αυλη*, inasmuch as in it we find considerable resemblance to the rectangular and columnar disposition of the comparatively more recent temple.

139. It would be a hopeless task to connect the steps that intervened between the sole use of the altar and the establishment of the temple in its perfection; though it might, did our limits permit the investigation, be more easy to find out the period when the regular temple became an indispensable appendage to the religion of the country. It is closely connected with that revolution which abolished the civil, judicial, and military offices of kings leaving the sacerdotal office to another class of persons. Though in the palace of the king no portion of it was appropriated to religious ceremony, the spot of the altar only excepted, yet, as it was the depository of the furniture and utensils requisite for the rite of sacrifice, when the palace was no more, an apartment would be wanting for them; and this, conjoined with other matters, may have suggested the use of the cell. Eusebius has conjectured that the temple originated in the reverence of the ancients for their departed relations and friends, and that they were only stately monuments in honour of heroes, from whom the world had received considerable benefit, as in the case of the temple of Pallas, at Larissa, really the sepulchre of Acrisius, and the temple of Minerva Polias at Athens, which is supposed to cover the remains of Erichthonius. The passage in Virgil (*Æn.* ii. v. 74.)—

> ——— tumulum antiquæ Cereris, sedemque sacratam
> Venimus —

is explanatory of the practice of the ancients in this respect; and, indeed, it is well known that sacrifices, prayers, and libations were offered at almost every tomb; nay, the resting-place of the dead was an asylum or sanctuary not less sacred than was, afterwards, the temple itself. From Strabo (lib. ii.) it is clear that the temple was not always originally a structure dedicated to a god, but that it was occasionally reared in honour of other personages.

140. Before proceeding to that which is more accurately known, it may not be uninstructive to the reader to glance at the houses of the Greeks, as may be gathered from passages in the Iliad and the Odyssey. We shall merely remind him that Priam's house had fifty separate chambers, though he lived in a dwelling apart from it. These houses were, in some parts, two stories in height, though the passages militating against that assertion (*Iliad*, B. 514—16. 184.) have been pronounced of doubtful antiquity. There is, however, not the slightest doubt that the dwellings of the East consisted of more than a single story. David wept for Absalom in the chamber *over* the gate (2 *Sam.* xviii. 33.). The altars of Ahaz were on the terrace of the *upper chamber* (2 *Kings*, xxii. 12.). The summer chamber of Eglon had *stairs* to it, for by them Ehud escaped, after he had revenged Israel (1 *Judges*, iii. 20.; 1 *Kings*, vi. 8.). In the Septuagint, these upper stories are all represented by the word *ὑπερωον*, the same employed by Homer. The Jewish law required (*Deut.* xxii. 8.) the terraces on the tops of their houses to be protected by a battlement; and, indeed, for want of a railing (*Odyss.* K. 552. et seq.) of this sort, Elpenor, one of the companions of Ulysses, at the palace of Circe, fell over and broke his neck. The use of the word *κλιμαξ* in the Odyssey, connected with the words *αναβαινειν* and *καταβαινειν*, and the substantive *ὑπερωον*, is of frequent occurrence: it is either a ladder or a staircase, and which of them is unimportant; but it clearly indicates an upper story. To a comparatively late period, the Greek temple was of timber. Even statues of the deities were, in the time of Xenophon, made in wood for the smaller temples (lib. iv. c. 1.), where the revenue of them was not adequate to afford a more expensive material. But time and accidents would scarcely permit their prolonged duration, and none survived long enough to allow of a proper description of them reaching us. The principle of their construction necessarily bore some relation to the materials employed, and the use of stone must have imparted new features to them. In timber, the beam (*epistylium*), which was borne by the columns, would probably extend in one piece through each face of the building. But in a stone construction this could not take place, even had blocks of such dimensions been procurable, and had mechanical means been at hand to place them in their proper position. From this alone follows a diminution of spaces between the columns. The arch, be it recollected, was unknown. It is curious to observe that the relative antiquity of the examples of Grecian Doric may be expressed in terms of the intercolumniations; that is, the number of diameters forming the intervals between the columns. There is, moreover, another point worthy of notice, which is, that their antiquity may be also estimated by the comparison of the heights of the columns compared with their diameters. This, however, will require

further consideration when we come to treat of the orders: here it is noticed only incidentally. Though we are not inclined to place reliance on the account given by Vitruvius of the origin of the orders of architecture, we should scarcely be justified in its omission here. It seems necessary to notice it in any work on architecture; and, after remarking that the age which that author assigns for their origin is long before Homer's time, at which there seems no probability of their existence, from the absence of all reference to them in his poems, we here subjoin the account of Vitruvius (lib. iv. c. 1.):—"Dorus, son of Hellen and the Nymph Orseis, reigned over Achaia and Peloponnesus. He built a temple of this (the Doric) order, on a spot sacred to Juno, at Argos, an ancient city. Many temples similar to it were afterwards raised in the other parts of Achaia, though, at that time, its proportions were not precisely established. When the Athenians, in a general assembly of the states of Greece, sent over into Asia, by the advice of the Delphic oracle, thirteen colonies at the same time, they appointed a governor over each, reserving the chief command for Ion, the son of Xuthus, and Creusa, whom the Delphic Apollo had acknowledged as son. He led them over into Asia, where they occupied the borders of Caria, and built the great cities of Ephesus, Miletus, Myus (afterwards destroyed by inundation, and its sacred rites and suffrages transferred by the Ionians to the inhabitants of Miletus), Priene, Samos, Teos, Colophon, Chios, Erythræ, Phocæa, Clazomene, Lebedos, and Melite. This last, as a punishment for the arrogance of its citizens, was detached from the other states in the course of a war levied on it, in a general council, and in its place, as a mark of favour towards king Attalus and Arsinoe, the city of Smyrna was received into the number of the Ionian states. These received the appellation of Ionian, after the Carians and Lelegæ had been driven out, from the name of Ion, the leader. In this country, allotting different sites to sacred purposes, they erected temples, the first of which was dedicated to Apollo Panionius. It resembled that which they had seen in Achaia, and from the species having been first used in the cities of Doria, they gave it the name of Doric. As they wished to erect this temple with columns, and were not acquainted with their proportions, nor the mode in which they should be adjusted, so as to be both adapted to the reception of the superincumbent weight, and to have a beautiful effect, they measured a man's height by the length of the foot, which they found to be a sixth part thereof, and thence deduced the proportions of their columns. Thus the Doric order borrowed its proportion, strength, and beauty from the human figure. On similar principles, they afterwards built the temple of Diana; but in this, from a desire of varying the proportions, they used the female figure as a standard, making the height of the column eight times its thickness, for the purpose of giving it a more lofty effect. Under this new order, they placed a base as a shoe to the foot. They also added volutes to the capital, resembling the graceful curls of the hair, hanging therefrom, to the right and left, certain mouldings and foliage. On the shaft, channels were sunk, bearing a resemblance to the folds of a matronal garment. Thus were two orders invented; one of a masculine character, without ornament, the other of a character approaching the delicacy, decorations, and proportions of a female. The successors of these people, improving in taste, and preferring a more slender proportion, assigned seven diameters to the height of the Doric column, and eight and a half to the Ionic. That species, of which the Ionians were the inventors, has received the appellation of Ionic. The third species, which is called Corinthian, resembles, in its character, the graceful elegant appearance of a virgin, whose limbs are of a more delicate form, and whose ornaments should be unobtrusive. The invention of the capital of this order arose from the following circumstance. (*Fig.* 93.) A Corinthian virgin, who was of marriageable age, fell a victim to a violent disorder: after her interment, her nurse, collecting in a basket those articles to which she had shown a partiality when alive, carried them to her tomb, and placed a tile on the basket, for the longer preservation of its consents. The basket was accidentally placed on the root of an acanthus plant, which, pressed by the weight, shot forth, towards spring, its stems and large foliage, and in the course of its growth, reached the angles of the tile, and thus formed volutes at the extremities. Callimachus, who, for his great ingenuity and taste in sculpture, was called by the Athenians κατατεχνος, happening at this time to pass by the tomb, observed the basket and the delicacy of the foliage that surrounded it. Pleased with the form and novelty of the combination, he took the hint for inventing these columns, using them in the country about Corinth," &c. Now, though we regret to damage so elegant and romantic a story, we must remind those who would willingly trust the authority we have quoted, that Vitruvius speaks of matters which occurred so long before his time, that in such an investigation as that before us we must have other authentication than that of the author we quote, and most especially in the case of the Corinthian capital, whose type may be referred to in a

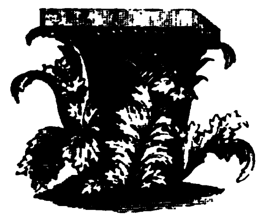


Fig. 93. ORIGIN OF CORINTHIAN CAPITAL.

vast number of the examples of Egyptian capitals, one of which, among many, is seen in *fig.* 94.

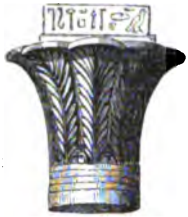


Fig. 94. EGYPTIAN CAPITAL.

141. The progress of the art in Greece, whose inhabitants, in the opinion of the Egyptian priests in the time of Solon, were so ignorant of all science that they neither understood the mythology of other nations nor their own (Plato, in *Timæo*), cannot be satisfactorily followed between the period assigned to the siege of Troy and the time of Solon and Pisistratus, or about 590 B. C. But it is, however, certain that within four centuries after Homer's time, notwithstanding their originally coarse manners, the Grecians attained the highest excellence in the arts. Goguet is of opinion the nurture of the art was principally in Asia Minor, in which country, he thinks, we must seek for the origin of the Doric and Ionic orders, whilst in Greece Proper the advancement was slow. The Corinthian order was, however, the last invented, and it seems generally agreed that its invention belongs to the mother country; but this we shall not stop to discuss here. The Temple of Jupiter, at Olympia, one of the earliest temples of Greece (Pausanias, *Eliac. Pr.* c. 10.), was was built about 630 years before the Christian era; and after this period were reared temples at Samos, Priene, Ephesus, and Magnesia, and other places up to that age when, under the administration of Pericles, the architecture of Greece attained perfection, and the highest beauty whereof it is supposed to be susceptible, in the Parthenon (*fig.* 95.) at Athens. The date of the erection of the temple of Diana, at Ephesus, was really as remote as that of the temple we have just mentioned. If Livy had sufficiently our confidence, and we concede that other writers corroborate his statement (lib. i. c. 45.), its date is as ancient as the time when Servius Tullius was king of Rome. Great, however, as were the works which the Grecians executed, the mechanical powers were, if one may judge from Thucydides (lib. iv.), not compendiously applied for raising weights.

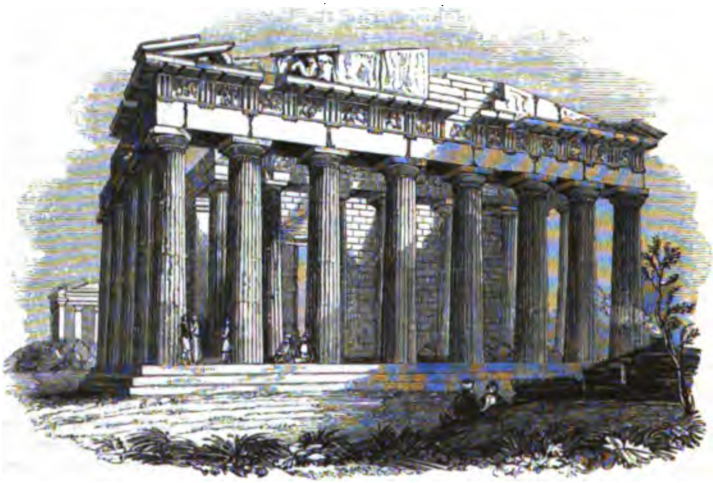


Fig. 95. VIEW OF THE PARTHENON.

142. The origin of the Doric order is a question not easily disposed of. Many provinces of Greece bore the name of Doria; but a name is often the least satisfactory mode of accounting for the birth of the thing which bears it. We have already attempted to account for the parts of this order by a reference to its supposed connection with the hut. The writer, in the *Encyclopedie Méthodique*, truly says that if the Doric had an *inventor*, that inventor was a people whose wants were, for a long period, similar, and with whom a style of building prevailed suitable to their habits and climate, though but slowly modified and carried to perfection. At the beginning of this section, we have, however, sufficiently spoken on this matter. But there are some peculiarities to be noticed with respect to the Doric order, which we think will be better given here than in the third book, where we propose to treat of the orders more fully; and these consist in the great differences which are found in its proportions and parts in different examples. For this purpose, several buildings have been arranged in the following table, wherein the first column exhibits the name of the building; the second the height of the column, of the example as a nume-

rator, and its lower diameter as a denominator, both in English feet; the third is the quotient of the second, showing the height of the column, expressed in terms of its lower diameter; the fourth column shows the height of the entablature in terms of the diameter of the column; the fifth column gives the distance between the columns in the same terms; and the sixth shows the height of the capitals also in the same terms: —

Example.	Height divided by lower Diameter in English Feet.	Diameters high.	Height of Entablature in Terms of Diameter.	Interco-lumniations.	Height of Capital in terms of Diameter.
Temple at Corinth - - - - -	$\frac{23{\cdot}713}{5{\cdot}83} =$	4·065	. .	1·362	·405
Hypæthral Temple at Pæstum - -	$\frac{28{\cdot}950}{7{\cdot}00} =$	4·134	1·741	1·167	·549
Enneastyle Temple at Pæstum - -	$\frac{21{\cdot}000}{4{\cdot}85} =$	4·329	1·140	1·064	·500
Greater Hexastyle Temple at Selinus -	$\frac{32{\cdot}678}{7{\cdot}49} =$	4·361	2·200	1·490	·490
Temple of Minerva at Syracuse - -	$\frac{28{\cdot}665}{6{\cdot}50} =$	4·410	. .	. .	·486
Octastyle Hypæthral Temple at Selinus -	$\frac{48{\cdot}585}{10{\cdot}62} =$	4·572	2·038	1·023	·450
Temple of Juno Lucina at Agrigentum -	$\frac{21{\cdot}156}{4{\cdot}59} =$	4·606	. .	. .	·570
Temple of Concord at Agrigentum -	$\frac{22{\cdot}062}{4{\cdot}64} =$	4·753	1·976	1·071	·487
Hexastyle Temple at Pæstum - -	$\frac{20{\cdot}353}{4{\cdot}24} =$	4·795	1·917	1·111	·564
Temple of Jupiter Panhellenius at Egina -	$\frac{17{\cdot}351}{3{\cdot}22} =$	5·395	. .	1·680	·486
Parthenon - - - - - -	$\frac{34{\cdot}232}{6{\cdot}15} =$	5·566	1·977	1·275	·459
Temple of Theseus at Athens - -	$\frac{18{\cdot}717}{3{\cdot}30} =$	5·669	1·964	1·250	·502
Temple of Minerva at Sunium - -	$\frac{19{\cdot}762}{3{\cdot}34} =$	5·899	1·928	1·472	·372
Doric Portico of Augustus at Athens -	$\frac{26{\cdot}206}{4{\cdot}33} =$	6·042	1·724	1·046	·374
Temple of Apollo, Island of Delos - -	$\frac{18{\cdot}721}{3{\cdot}092} =$	6·052	1·900	1·500	·555
Temple of Jupiter Nemeus - - -	$\frac{33{\cdot}932}{5{\cdot}22} =$	6·515	1·560	1·348	·383
Portico of Philip of Macedon - -	$\frac{19{\cdot}330}{2{\cdot}96} =$	6·535	1·867	2·700	·480

143. Casting our eye down the third column of the above table, we find the height of the column in terms of its lower diameter varying from 4·065 to 6·535. Lord Aberdeen (*Inquiry into the Principles of Beauty in Greek Architecture*, 1822) seems to prefer the proportion of the capital to the column, as a test for determining its comparative antiquity; but we are not, though it is entitled to great respect, of his opinion, preferring, as we do, a judgment from the height as compared with the diameter to any other criterion; although it must be admitted that it is not an infallible one. The last columns shows what an inconstant test the height of the capital exhibits. There is another combination, to which reference ought to be made, — the height of the entablature, which forms the third column of the table, in which it appears that the most massive is about one third the height of the whole order, and the lightest is about one fourth, and that these proportions coincide with the thickest and the thinnest columns.

144. The entasis or swelling, which the Greeks gave to their columns, and first verified by the observations of Mr. Allason, was a refinement introduced probably at a late period, though the mere diminution of them was adopted in the earliest times. The practice is said to have its type in the law which Nature observes in the formation of the trunks of trees. This diminution varies, in a number of examples, from one fifth to one third of the lower diameter; a mean of sixteen examples gives one fourth. The mere diminution is not, however, the matter for consideration; but the curved outline of the shaft, which is attributed to some refined perception of the Greeks,

relative to the apparent diminution of objects as their distance from the eye was increased, which Vitruvius imagines it was the object of the entasis to correct. It cannot be denied that in a merely conical shaft there is an appearance of concavity, for which it is difficult to account. The following explanation of this phenomenon, if it may be so called, is given by our esteemed and learned friend, Mr. Narrien, in the *Encyc. Metropol.* art. Architecture. "When," he observes, "we direct the axis of the eye to the middle of a tall column, the organ accommodates itself to the distance of that part of the object, in order to obtain distinctness of vision, and then the oblique pencils of light from the upper and lower parts of the column do not so accurately converge on the retina: hence arises a certain degree of obscurity, which always produces a perception of greater magnitude than would be produced by the same object if seen more distinctly. The same explanation may serve to account for the well-known fact, that the top of an undiminished pilaster appears so much broader than the body of its shaft; to which, in this case, may be added some prejudice, caused by our more frequently contemplating other objects, as trees, which taper towards their upper extremities." Connected in some measure with the same optical deception is the rule which Vitruvius lays down (book iii. chap. 2.) for making the columns, at the angles of buildings, thicker than those in the middle by one fiftieth part of a diameter,—a law which we find followed out to a much greater extent in the temples of the Parthenon and of Theseus, at Athens, where the columns at the angles exceed in diameter the intermediate ones by one forty-fourth and one twenty-eighth respectively. Where, however, the columns were viewed against a dark ground, some artists think that a contrary deception of the eye seems to take place.

145. In the investigation of the Doric order, among its more remarkable features are to be noted the longitudinal striæ, called *flutes*, into which the column is cut; every two whereof unite, in almost every case, in an edge. Their horizontal section varies in different examples. In some, the flutes are formed by segments of circles; in others, the form approaches that of an ellipsis. The number all round is usually twenty; such being the case at Athens; but at Pæstum the exterior order of the great temple has twenty-four, the lower interior order twenty, and the upper interior sixteen only. It has been strangely imagined, by some, that these flutings, which, be it remembered, are applied to the other orders as well as to the Doric, were provided for the reception of the spears of persons visiting the temples. The conjecture is scarcely worth refutation, first, because no situation for the *δουροδοκη* (place for spears) would have led to their more continual displacement from accident; and secondly, because of the sloping or hemispherical form in the other orders, the foot of the spear must have immediately slid off. Their origin may probably be found in the polygonal column, whose sides received a greater play of light by being hollowed out,—a refinement which would not be long unperceived by the Greeks.

146. We shall now notice some of the more important Doric edifices, as connected with the later history of the Doric order, which was that most generally used by the European states of Greece, up to their subjugation by the Romans. The temple of Jupiter Panhellenius, at Egina, is probably one of the most ancient in Greece. The story, however, of Pausanias, that it was built by Æacus, before the war of Troy, is only useful as showing us its high antiquity. (*Fig.* 96.) The proportions of its columns and entablature are to be

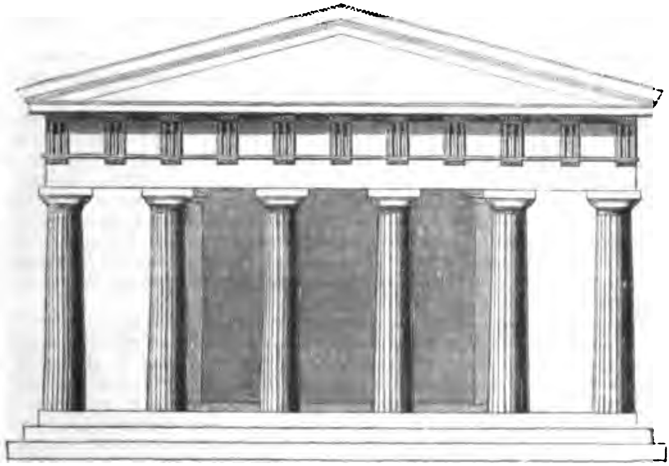


Fig. 96. ELEVATION OF THE TEMPLE OF JUPITER PANHELLENIUS.

found in a preceding page. The sculpture with which this building was decorated is now at Munich. Though, perhaps, not so old as the building itself, it is of an antiquity coeval with the Persian invasion. The name of the architect of this temple was Libon, of whom no other work is known; its age is, perhaps, from about 600 years before Christ. The Doric temple at Corinth, of which five columns, with their architrave, are still in existence, is a very early specimen of Grecian architecture. The assertion that it was dedicated to Venus is unsupported by testimony.

147. The Grecian temples in Sicily were erected at periods which it is not easy to fix; and with respect to them, we can only, from circumstances connected with the island, reason on the dates to be assigned to them. The founding of the city of Selinus or Selinuns, on the south-west coast of the island, has usually been attributed to a colony from Megara; but we are of opinion with the Baron Pisani (*Memoria sulle Metope Selinuntine*) that it existed as a Phœnician city long previous to the settlement there by the Megaræans. The style and forms of the sculpture of the Selinuntine temples seem to bear marks of a remoter age than is usually allowed to them, that is, 500 years B. C. Of the means and the circumstances under which they were raised we are ignorant; but their ruins sufficiently indicate the wealth and power that were employed upon them, as well as a considerably advanced state of the art.

148. The temple of Jupiter Olympius, the largest in the island, and one of the most stupendous monuments of antiquity, was, as we learn from Diodorus (lib. xiii. p. 82.), never completed. The Agrigentines were occupied upon it when the city was taken by Hamilcar, in the 93d Olympiad. Its columns were on such a scale that their flutes were sufficiently large to receive the body of a man. The temples of Peace and of Concord, in the few vestiges that remain of them, attest the ancient magnificence of the city of Agrigentum, and are among the most beautiful as well as the best preserved remains of antiquity. A Corinthian colony established itself at Syracuse, as is said, 750 B. C.; but no details of the history of the city furnish us with the means of ascertaining when the first temples there were erected. Its riches and magnificence were, however, such that it soon became an object of temptation to the Carthaginians. Its temple of Minerva is evidently of very remote antiquity.

149. The great Hypæthral temple at Pæstum was probably constructed during the period that the city was under the power of the Sybarites, who dispossessed its original inhabitants, enjoying, for upwards of two hundred years, the fruits of their usurpation. Marks of Greek art are visible in it, and the antiquity of the Hypæthral temple itself is confirmed by the example. The city fell into the hands of the Lucanians about 350 years B. C.; after which, in about 70 years, it was a municipal town of the Roman empire. The following is perhaps the chronological order of the principal buildings of Sicily and Magna Græcia; viz. Syracuse, Pæstum, Selinus, Segesta, and Agrigentum.

150. The dates of the edifices at Athens are, without difficulty, accurately fixed. The Propylæum (*figs.* 97 and 98.) was commenced by Mnesicles about 437 B.C., and, at a great

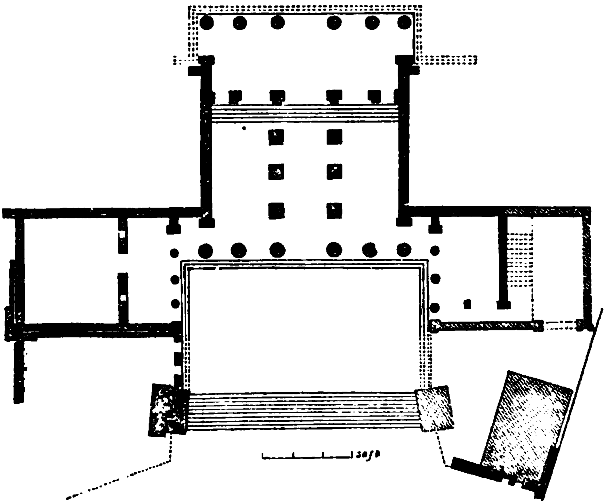


Fig. 97. PLAN OF PROPYLÆUM.

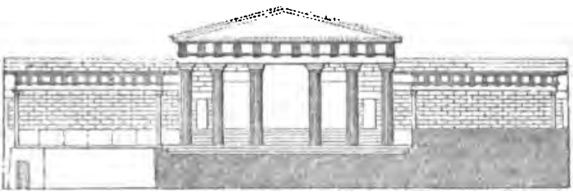


Fig. 98. ELEVATION OF THE PROPYLÆUM.

expense, was completed in five years. It is a specimen of the military architecture of the period, and at the same time forms a fine entrance to the Acropolis of Athens. At the rear of its Doric portico the roof of the vestibule was supported within by two rows of Ionic columns, whose bases still remain. By the introduction of these an increased height was obtained for the roof, the abaci of the Ionic capitals being thus brought level with the exterior frieze of the building. The Parthenon (*figs.* 99. and 100.) erected a few years later under the superintendence of Ictinus, is well known as one of the finest remains of antiquity.

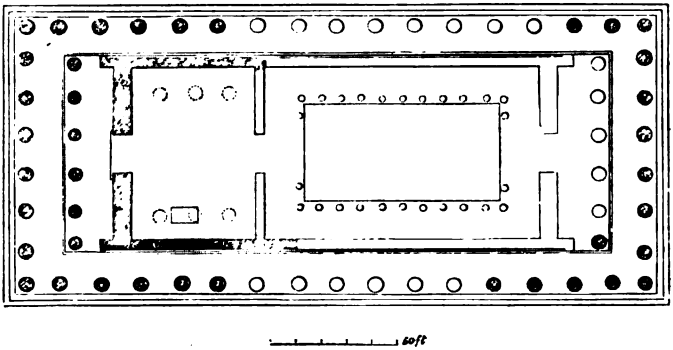


Fig. 99. PLAN OF THE PARTHENON.

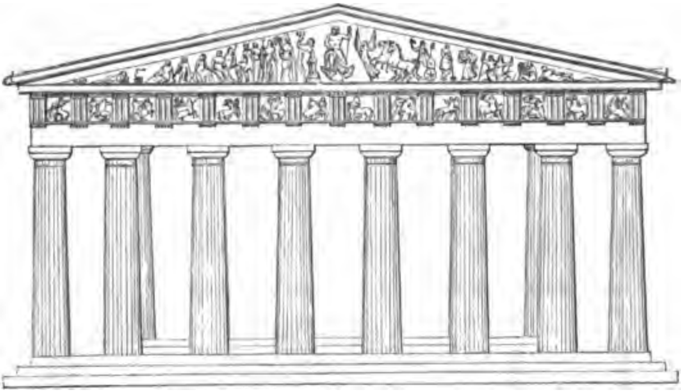


Fig. 100. ELEVATION OF THE PARTHENON.

As well as the building last mentioned, it was reared at the period when Pericles had the management of public affairs, and was without a rival in Athens. Phidias was the superintendent sculptor employed; and many of the productions which decorated this magnificent edifice have doubtless become known to the reader in his visits to the British Museum, where a large portion of them are now deposited. Nearly coeval with the Propylæum and Parthenon, or perhaps a little earlier, is the temple of Theseus (*fig.* 101.), which was, it is supposed, erected to receive the ashes of the national hero, when removed from Scyros to Athens. The ruins of the architectural monuments of this city attest that the boasted power and opulence of Greece was not an idle tale. Pericles, indeed, was charged by his enemies with having brought disgrace upon the Athenians by removing the public treasures of Greece from Delos, and lavishing them in gilding their city, and ornamenting it with statues and temples that cost a thousand talents, as a proud and vain woman tricks herself out with jewels. (*Plutarch's Life of Pericles.*) The temple of Minerva, at Sunium, was probably by Ictinus; but one of the happiest efforts of this architect was the temple of Apollo Epicurius, in Arcadia, still nearly entire. The peculiarities found in it we will shortly detail. The front has six columns, and instead of thirteen in each flank (the usual number) there are fifteen. In the interior, buttresses on each side, to the number of six, return inwards from the walls of the cell, each ending in semicircular pilasters of the Ionic order. These seem to have been brought up for the facility of supporting the roof, which was of stone. With the exception of the temple of Minerva at Tegea, its reputation for beauty was such, that it surpassed, if that be a true test, all other buildings in the Peloponnesus. Its situation is about three or four miles from the ruins of Phigalia, on an elevated part of Mount Cotylus, commanding a splendid landscape, which is terminated by the sea in the distance.

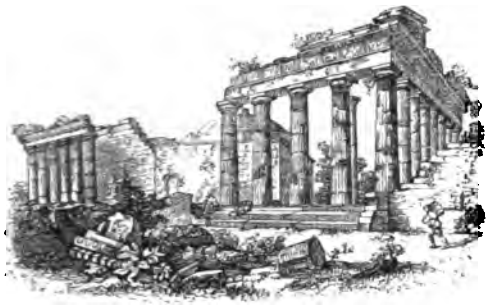


Fig. 101. TEMPLE OF THESEUS.

151. About 370 B.C., Epaminondas restored the Messenians to independence, and built the city of Messene. The ruins still extant prove that the art at that period had not materially declined. Its walls, in many parts, are entire, and exhibit a fine example of Grecian military architecture in their towers and gates. At no distant time from the age in question the portico of Philip of Macedon, at least his name is inscribed on it, shows that the Doric order had undergone a great change in its proportions. This portico must have been erected about 338 B.C., and after it the Ionic order seems to have been more favoured and cultivated. The last example of the Doric is perhaps the portico of Augustus, at Athens.

152. Before proceeding to the investigation of the Ionic order, it may here, perhaps, be as well to speak of the proportions between the length and breadth of temples, as compared with the rules given by Vitruvius (book iv. chap. 4.), that the length of a temple shall be double its breadth, and the cell itself in length one fourth part more than the breadth, including the wall in which the doors are placed. Though in the Greek examples these proportions are approximated, an exact conformity with the rule is not observed in any. The length, for instance, of the temple of Jupiter, at Selinus, is to the breadth as 2·05 to 1; in the temple of Theseus, as 2·3 to 1; and from the mean of six examples of the Doric order, selected in Greece and Sicily, is 2·21 to 1. If the flanks be regulated in length by making the number of intercolumniations exactly double those in front, it will be immediately seen that the proportions of Vitruvius are obtained on a line passing through the axes of the columns. But as in most of the Greek temples the central intercolumniation in front is wider than the rest, the length of the temple would necessarily be less than twice the width. In the earlier specimens of the Doric order the length is certainly, as above mentioned in the temple of Jupiter at Selinus, very nearly in accordance with the rule; but in order to counteract the effect of the central intercolumniation being wider, the number of columns, instead of intercolumniations on the flank, is made exactly double those in front. In the later examples, however, as in the temples of Theseus and the Parthenon, and some others, the number of intercolumniations on the flank was made double the number of columns in the front, whence the number of columns on the flanks was double the number of those in front and one more; so that the proportion became nearly in the ratio of 2·3 to 1. The simplicity which flowed from these arrangements in the Grecian temples was such that it seems little more than arithmetical architecture,—so symmetrical that from the three data, the diameter of the column, the width of the intercolumniation, and the number of columns in front, all the other parts might be found.

153. The Ionic order, at first chiefly confined to the states of Asia Minor, appears to have been coeval with the Doric order. The most ancient example of it on record is the temple of Juno, at Samos. Herodotus (*Euterpe*) says, it was one of the most stupendous edifices erected by the Greeks. In the *Ionian Antiquities* (2d edit. vol. i. c. 5.) is to be found an account of its ruins. It was erected about 540 years B.C., by Rhæcus and Theodorus, two natives of the island. The octastyle temple of Bacchus, at Teos, in whose praise Vitruvius was lavish, shows by its ruins that the old master of our art was well capable of appreciating the beauties of an edifice. Hermogenes, of Alabanda, was its architect, and he seems to have been the promoter of a great change in the taste of his day. Vitruvius (lib. iv. c. 3.) tells us that Hermogenes, "after having prepared a large quantity of marble

for a Doric temple, changed his mind, and, with the materials collected, made it of the Ionic order, in honour of Bacchus." We are bound, however, to observe upon this, that the story is not confirmed by any other writer. It is probable that this splendid building was raised after the Persian invasion; for, according to Strabo (lib. xiv.), all the sacred edifices of the Ionian cities, Ephesus excepted, were destroyed by Xerxes. Besides this octastyle temple, those of Apollo Didymæus, near Miletus, built about 376 B.C., and of Minerva Polias, at Priene, dedicated by Alexander of Macedon, are the chief temples of this order of much fame in the colonies. We shall therefore confine our remaining remarks to the three Ionic temples at Athens, and shall, as in the Doric order, subjoin a synoptical view of their detail.

Example.	Height divided by lower Diameter, in English Feet.	Diameters high.	Height of Entablature in terms of Diameter.	Interco-lumniations.	Height of Capital in terms of Diameter.	Upper Diameter, lower Diam. being 1·000.
Temple on the Ilyssus -	$\frac{14\ 694}{1{\cdot}783}$ =	8 241	2·265	2·090	0·610	·850
Temple of Minerva Polias -	$\frac{25{\cdot}387}{2{\cdot}786}$ =	9·119	2·287	3·500	0·700	·833
Temple of Erectheus -	$\frac{21{\cdot}625}{2{\cdot}317}$ =	9·337	. .	2·000	0·773	·816

154. We here see that the Ionic column varies in height from eight diameters and nearly a quarter to nearly nine and a half, and the upper diameter in width between $\frac{85}{100}$ and $\frac{816}{1000}$. The dissimilarity of the capitals renders it impossible to compare them. The mean height of the entablature is about a fourth of the height of the whole order. The height of the Grecian Ionic cornice may be generally considered as two-ninths of the whole entablature.

155. The age of the double temple of Minerva Polias (*fig.* 102.) and Erectheus has not been accurately ascertained. From the earliest times these personages were held in high veneration by the Athenians, and it is more than likely that a confusion has arisen between the ancient and modern edifices. The former was partially destroyed by Xerxes, and there is no certainty that the latter was restored by Pericles.

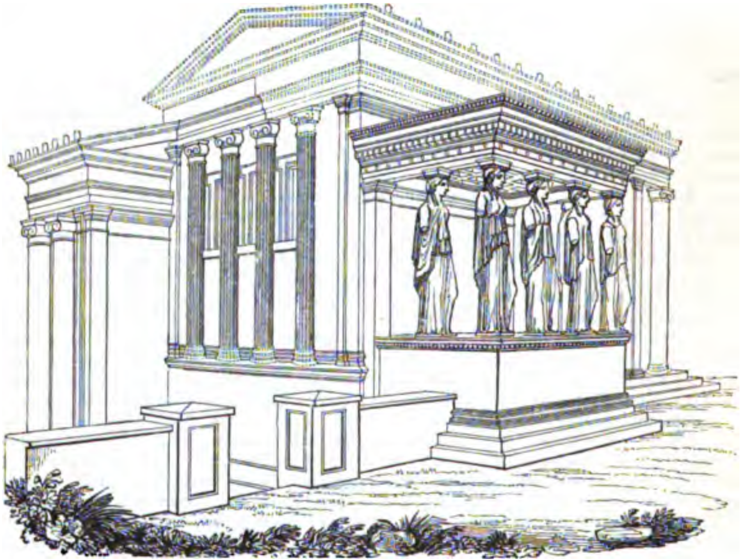


Fig. 102. TEMPLES OF MINERVA POLIAS AND ERECTHEUS.

156. In the bases applied to the order in the Athenian buildings there are two *tori*, with a *scotia* or *trochilus* between them, a fillet below and above the scotia separating it from the tori. The upper fillet generally coincides with a vertical line let fall from the extreme projection of the upper torus. In the temple on the Ilyssus the lower fillet projects about half the distance between the hollow of the scotia and the extremity of the inferior torus. The height of the two tori and scotia are nearly equal, and a bead is placed on the upper

torus for the reception of the shaft of the column. The temples of Erectheus and that on the Ilyssus have the lower tori of their bases uncut, whilst the upper ones are fluted horizontally. In that of Minerva Polias, the upper torus is sculptured with a *guilloche*. The base just described is usually denominated the Attic Base, though also used in the colonies. The bases, however, of the temples of Minerva Polias at Priene, and of Apollo Didymæus near Miletus, are very differently formed.

157. The Volute, the great distinguishing feature of the order, varies considerably in the different examples. In the edifices on the Ilyssus and at Priene, as well as in that of Apollo Didymæus, the volute has only one channel between the revolutions of the spiral; whilst in those of Erectheus and Minerva Polias, at Athens, each volute is furnished with two distinct spirals and channels. In the temple on the Ilyssus, the capital is terminated a little below the eye of the volute; in the others it reaches below the volutes, and is decorated with honeysuckle flowers and foliage. The number of flutes, which on the plan are usually elliptical, is twenty-four, and they are separated by fillets from each other. In some examples they descend into the apophyge of the shaft.

158. The tomb of Theron, at Agrigentum, in which Ionic columns and capitals are crowned with a Doric entablature, has, by some, been quoted as an example of the Ionic order; but we do not believe it to be of any antiquity, and, if it were, it is so anomalous a specimen that it would be useless to pursue any inquiry into its foundation.

159. In the *antæ* or pilasters of this order, as well as of the Doric, their capitals differ in profile from the columns, and are never decorated with volutes. Their breadth is usually less than a diameter of the column, and they are not diminished.

160. The highest degree of refinement of Greek architecture is exhibited in its examples of the Corinthian order, whose distinguishing feature is its capital. We have, in a preceding page (139), given Vitruvius's account of its origin; but we much doubt whether Callimachus was its inventor.

161. The capitals of Egyptian columns are so close upon the invention, that we apprehend it was only a step or two in advance of what had previously been done. The palm leaf, lotus flower, and even volutes, had been used in similar situations in Egypt, and the contour of the lotus flower itself bears no small resemblance to the bell of the Corinthian capital.

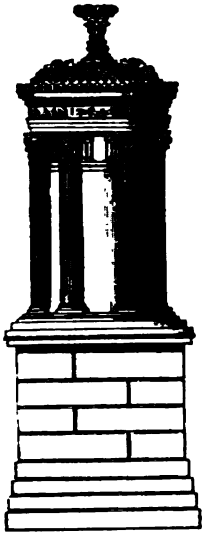


Fig. 103. CHORAGIC MONUMENT OF LYSICRATES.

162. We are inclined to assign the period of the latter part of the Peloponnesian war as that in which the order first came into use. We find from Pausanias (*Arcad.* c. 45.) that Scopas, the celebrated architect of Paros, rebuilt the temple of Minerva at Tegæa, which was destroyed by fire about 400 years B.C., and that, according to that author, it was the largest and most beautiful edifice in the Peloponnesus. The cell, which was hypæthral, was surrounded by two ranks of Doric columns, which were surmounted by others of the Corinthian order. The peristyle of this temple was Ionic.

163. The delicacy of formation of this order has, doubtless, subjected its examples to earlier destruction and decay than have attended the other orders: hence our knowledge of it is almost confined to the examples we meet of it in the Tower of the Winds, and the Choragic monument of Lysicrates (*fig.* 103.), both at Athens; the former whereof can scarcely be considered Corinthian, and the latter not very strictly so. It was erected about 330 years B.C., as appears from the inscription on the frieze. These Choragic buildings, usually of small dimensions, were erected in honour of those who, as choragi or leaders of the chorus in the musical games, were honoured with the prize, which was a tripod. The following are the proportions observed in the Choragic monument of Lysicrates: —

Height of columns in English feet		11·637
Height of columns in terms of lower diameter		10·318
Height of capital in terms of lower diameter		1·216
Upper diameter of shaft in terms of the lower diameter		0·833
Height of the architrave in terms of the lower diameter	0·850	
Height of the frieze in terms of the lower diameter	0·483	
Height of cornice in terms of the lower diameter	0·833	
Total height of entablature in terms of the lower diameter		2·166

From which it appears that the entablature is less than a fifth of the total height of the order. The intercolumniations are 2·200 diameters. The base is little different from that used in the Ionic order.

164. In the ornaments applied for the decoration of the sacred edifices of the Greeks,

they imitated the real and symbolical objects used in their worship. Thus, at the temple of Apollo at Teos, the lyre, tripod, and griffin occur; in the Temple of the Winds at Athens, the winds are personified on the walls; the Choragic monument of Lysicrates exhibits the consequences of a contempt of music; on the temple of Victory, at the entrance of the Acropolis, was recorded, on the very spot, the assault and repulsion of the Amazons; the Lapithæ are vanquished again in the temple of Theseus, the founder of the city; and lastly, in the Parthenon is brought before the eye, on a belt round the cell of the temple, the Panathenaic procession, which, issuing from the door of the cell, biennially perambulated the edifice, whilst its pediment perpetuates the contest between Neptune and Minerva for the honour of naming the city, and calls to remembrance the words of Cicero, " De quorum," (Atheniensium,) " urbis possessione, propter pulchritudinem etiam inter deos certamen fuisse proditum est," &c. In the capitals of the Corinthian examples just noticed the leaves are those of the olive, a tree sacred to the tutelary goddess of Athens, and on that account as well as its beauty of form and simplicity adopted by a people whose consistency in art has never been excelled.

165. Besides the method of supporting an entablature by means of columns, the employment of figures was adopted, as in the temples of Erectheus and Minerva Polias before mentioned (see *fig.* 102.). They were called *Caryatides;* and their origin, according to the account of it by Vitruvius (lib. i. c. 1.), was that Carya, a city of Peloponnesus, having assisted the Persians against the Grecian states, the latter, when the country was freed from their invaders, turned their arms against the Caryans, captured their city, put the males to the sword, and led the women into captivity. The architects of the time, to perpetuate the ignominy of the people, substituted statues of these women for columns in their porticoes, faithfully copying their ornaments and drapery. It is, however, certain that the origin of their application for architectural purposes is of far higher antiquity than the invasion of Greece by the Persians, and in the above account Vitruvius is not corroborated by any other writer. Herodotus (*Polymnia*), indeed, observes that some of the states whom he enumerates sent the required offering of salt and water to Xerxes; but no mention is made of Carya, whose conduct, if punished in such an extraordinary manner, would have been too curious a matter to have been passed over in silence. Whether the use of statues to perform the office of columns travelled into Greece from India or from Egypt, we will not pretend to determine. Both, however, will furnish examples of their application. In the latter country we find them employed in the tomb of King Osymandyas (*Diodorus*, tom. i. f. 56. Wesseling). Diodorus also, speaking of Psammeticus, says that having obtained the whole kingdom, he built a propylæum on the east side of the temple to the god at Memphis, which temple he encircled with a wall; and in this propylæum, instead of columns, substituted colossal statues (*κολοττοὺς ὑποστήσας*) twelve cubits in height.

166. The application of statues and representations of animals is a prominent feature in the architecture of Egypt, whereof the temple at Ibsambul is a striking example, though in that the figures do not absolutely carry the entablature (see *fig.* 71.). In India many instances of this use of statues occur, as in the excavations of the temple near Vellore described by Sir C. Mallet (*Asiat. Res.* vol. vi.), wherein heads of lions, elephants, and imaginary animals apparently support the roof of the cave of Jugnath Subba; and at Elephanta, where colossal statues are ranged along the sides as high as the underside of the entablature (see *fig.* 39.). But as the settlement of the claims of either of these countries to the invention is not our object, we shall proceed to consider how they obtained in Greece the name that has been applied to them long before the period of which Vitruvius speaks.

167. *Καρύα*, the nut tree (*Nux juglans*), which Plutarch (*Sympos.* lib. ii.) says received its name from its effect (*κάρος*, sopor) on the senses, was that into which Bacchus, after cohabitation with her, transformed Carya, one of the three daughters of Dion, king of Laconia, by his wife Iphitea. The other daughters, Orphe and Lyco, were turned into stones for having too closely watched their sister's intercourse with the lover. Diana, from whom the Lacedemonians learnt this story, was on that account, as well perhaps as the excellence of the fruit of the tree, therefore worshipped by them under the name of Diana Caryatis. (*Servius*, note on 8th Ecl. of Virgil, edit. Burman.) Another account, however, not at all affecting the hypothesis, is given of the name of Diana Caryatis in one of the old commentators of Statius (*Barthius*, lib. iv. v. 225.). It is as follows. Some virgins threatened with danger whilst celebrating the rites of the goddess, took refuge under the branches of a nut tree (*καρυα*), in honour and perpetuation whereof they raised a temple to Diana Caryatis. If this, however, be an allusion to the famous interposition of Aristomenes in protecting some Spartan virgins taken by his soldiers, it is not quite borne out by the words of Diodorus. Salmasius (*Exercit. Plinianæ*, f. 603. et seq.) says, that Diana was worshipped at Carya, near Sparta, under the name of Diana Caryatis; and that at her temple and statue the Lacedemonian virgins had an anniversary festival, with dancing, according to the custom of the country.

168. But to return more closely to the subject, we will give the words of Pausanias (*Laco-*

sica) on the temple to the goddess at Carya. "The third turning to the right leads to Carya, and the sanctuary of Diana; for the neighbourhood of Carya is sacred to that goddess and her nymphs. The statue of Diana Caryatis is in the open air; and in this place the Lacedemonian virgins celebrate an anniversary festival with the old custom of the dance." Kuhnius on the passage in question, after reference to Hesychius, says, "Caryatides etiam dicuntur Lacænæ saltantes, sinistrâ ansatæ, uti solebant Caryatides puellæ in honorem Dianæ."

169. From the circumstances above mentioned, we think it may be fairly concluded that the statues called Caryatides were originally applied to or used about the temples of Diana; and that instead of representing captives or persons in a state of ignominy, they were in fact representations of the virgins engaged in the worship of that goddess. It is probable that after their first introduction other figures, in buildings appropriated to other divinities, were gradually employed; as in the Pandroseum (attached to the temple of Minerva Polias), for instance, where they may be representations of the virgins called Canephoræ, who assisted in the Panathenaic procession. *Fig.* 104. is a representation of one of those used in the Pandroseum (see also *fig.* 102.); and *fig.* 105. is from the Townley collection, now in the British Museum. Piranesi conjectured that this last, with others, supported the entablature of an ancient Roman building restored by him from some fragments found near the spot where they were discovered, which is rather more than a mile beyond the Capo di Bove, near Rome. Four of the statues were found; and on one of the three, purchased by Cardinal Albani, the following inscription was found: — ΚΡΙΤΩΝ ΚΑΙ ΝΙΚΟΛΑΟΣ ΕΠΟΙΤΝ; showing that it was the work of Greek artists.

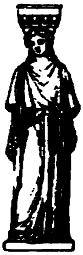


Fig. 104.

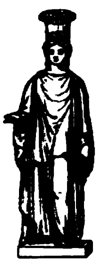


Fig. 105.

170. The republican spirit of Greece tended to repress all appearance of luxury in their private dwellings. The people seem to have thrown all their power into the splendour and magnificence of their temples; and it was not till a late period that their houses received much attention. Except in the open courts of them, it is difficult to conceive any application of the orders. It is certain that they frequently consisted of more than one story; but beyond this all is conjecture. In the time of Demosthenes (*Orat. adv. Aristocratem*) the private houses had begun to be increased in extent; and the description of them by Vitruvius, who knew Athens well, proves that they then erected on an extent implying vast luxury.

171. Within the last few years discoveries have been made at Athens, which would lead us to the belief that it was the practice of the Greeks to paint in party colours every portion of their temples, and that in violently contrasted colours. This has received the name of *polychrome architecture*. It is rather strange that no ancient writer has spoken of the practice, and the only way to account for the omission is by supposing it to have been so common that no one thought of mentioning it. From the information of M. Schaubert, the government architect at Athens, it appears that every part of the surface of the Parthenon had a coating of paint. That the coffers of the ceiling were painted, and its frieze ornamented with a fret in colours, was, he observes, known; but the whole building, he continues, as well as other temples, was thickly painted, in the metopæ, in the pediment, on the drapery of the figures, on the capitals, and on all the mouldings. So that, as he says with great simplicity, with its mouldings and carvings variously coloured, the simple Doric temple of Theseus was in effect richer than the most gorgeous example of Corinthian; and it would be worth the trouble to restore with accuracy a polychrome temple. From M. Quast (*Mittheilungen über Alt und Neu Athen*, Berlin, 1834), we learn that the colour was not used in a fluid state merely for the purpose of staining the marble, but in a thick coat, so that the material was completely covered; and that in the temple of Theseus this is more traceable than in any other. Though the colours, that of blue smalt more especially, have left but a grey crust, yet their original tone is still apparent. In this building deep blues and reds are the predominant colours, so as to relieve one another. The corona was deep blue, and the guttæ of a brown red; the foliage of the cymatium was alternately streaked with blue and red, the ground being green, which colour is applied to the small leaves on some of the lesser mouldings. Some of the coffers are coloured of a red inclining to purple, on which the ornament is given; others exhibit a blue ground, with red stars. The architrave of the portico was a bright red; the figures in the frieze were painted in their proper natural colours: traces of the colour show that the walls were green. It was not discovered that in the columns more than the arrises of the flutes were painted, although the echinus was. We do not doubt the accuracy of MM. Semper and Quast; but after all it is possible that all this painting may have been executed at a period much later than that of the buildings themselves.

172. The most ancient theatres of Greece were constructed in a temporary manner; but the little security from accident they afforded to a large concourse of persons soon made the Greeks more cautious for their security, and led to edifices of stone, which, in the end, ex-

ceeded in magnitude all their other buildings. Their form on the plan (see *fig.* 106.) was rather more than a semicircle, and consisted of two parts; the *σκηνὴ*, *scena*, and *κοιλον*, *cavea*.

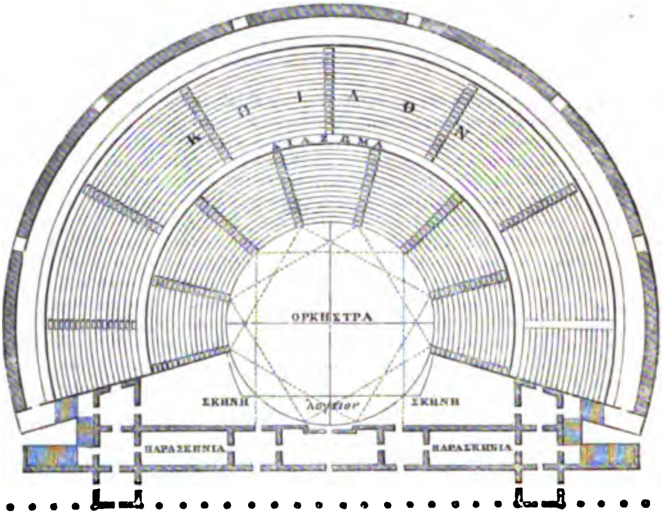


Fig. 106. PLAN OF A GREEK THEATRE.

The scena was at first merely a partition for the actors reaching quite across the stage, dressed with boughs and leaves, but in after times was very differently and more expensively constructed. It had three principal gates, two on the sides and one in the centre; at which last the principal characters entered. The whole scene was divided into several parts, whereof the most remarkable were—the *βροντεῖον*, *brontæum*, under the floor, where were deposited vessels full of stones and other materials for imitating the sound of thunder; the *επισκήνιον*, *episcenium*, a place on the top of the scene, in which were placed the machines for changing the various figures and prospects; the *παρασκήνιον*, *parascenium*, which served the actors as a dressing room; the *προσκήνιον*, *proscenium*, or stage, on which the performers acted; the *ορχήστρα*, *orchestra*, was the part in which the performers danced and sang, in the middle whereof was the *λογεῖον* or *θυμέλη*, *pulpitum*; the *υποσκήνιον*, *hyposcenium*, was a partition under the pulpitum, where the music was placed; the *κοῖλον*, *cavea*, was for the reception of the spectators, and consisted of two or three divisions of several seats, each rising above one another, the lowest division being appropriated to persons of rank and magistrates, the middle one to the commonalty, and the upper one to the women. Round the cavea porticoes were erected for shelter in rainy weather, the theatre of the Greeks having no roof or covering. The theatre was always dedicated to Bacchus and Venus, the deities of sports and pleasures; to the former, indeed, it is said they owe their origin: hence, the plays acted in them were called Διονυσιακὰ, *Dionysiaca*, as belonging to Διονυσος, or Bacchus. Every citizen shared by right in the public diversion and public debate; the theatre was therefore open to the whole community.

173. The Athenian *αγοραὶ*, or *fora*, were numerous; but the two most celebrated were the old and new forum. The old forum was in the Ceramicus within the city. The assemblies of the people were held in it, but its principal use was as a market, in which to every trade was assigned a particular portion.

174. The supply of water at Athens was chiefly from wells, aqueducts being scarcely known there before the time of the Romans. Some of these wells were dug at the public expense, others by private persons.

175. The first *gymnasia* are said to have been erected in Lacedemonia, but were afterwards much improved and extended, and became common throughout Greece. The gymnasium consisted of a number of buildings united in one enclosure, whereto large numbers resorted for different purposes. In it the philosophers, rhetoricians, and professors of all the other sciences, delivered their lectures; in it also the wrestlers and dancers practised and exercised; all which, from its space, they were enabled to do without interfering with one another. The chief parts (*fig.* 107.), following Vitruvius (lib. v. cap. 11.), are—A, the *περιστυλιον*, *peristylium*, which included the *σφαιριστὴριον*, *sphæristerium*, and *παλαίστρα*, *palestra*; 1, 2, 3, are the *στοαι*, *porticus*, with B B, *εξεδραι*, *exhedræ*, where probably the scholars used to meet; 4, 4, is the double portico looking to the south; C, *εφήβαιον*, *ephæbeum*, where the

ephebi or youths exercised, or, as some say, where those that designed to exercise met and agreed what kind of exercise they should contend in, and what should be the victor's reward; D, is the coryceum; E, the *κονιστήριον*, *conisterium*, where the dust was kept for sprinkling those that had been anointed; F is the cold bath (*frigida lavatio*); G, the *ελαιοθεσιον*, *elæothesium*, or place for anointing those that were about to wrestle; H, the *frigidarium*, or cold chamber; I, passage to the *propigneum*, or furnace; L, the propigneum; M, the arched *sudatio*, for sweating; N, the *laconicum*; O, the hot bath (*calida lavatio*); 5, 7, the two porticoes described as out of the palæstra, of which 7 forms the *xystus*, and 6 a double portico; *a a*, the *margines*, or *semitæ* of the xystus, to separate the spectators from the wrestlers; *b b*, the middle part excavated two steps, *c c*, down; Q Q, gardens; *d d*, walks; *e e*, *stationes* for seats; R R, *ξύστα*, *xysta*, sometimes called *περίδρομιδες*, for walking or exercises; S, the *stadium*, with raised seats round it.

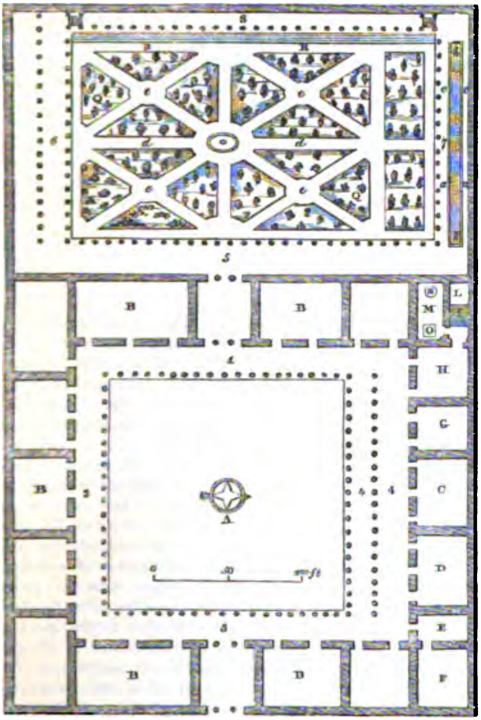


Fig. 107. PLAN OF A GREEK GYMNASIUM.

176. The roofs of the edifices of Athens vary from 14½ to 15½ degrees in inclination, a subject which will be hereafter fully considered, when we come to investigate the principles of constructing roofs. In Rome, as will hereafter be seen, the inclination is much more. There is nothing to warrant us in a belief that the arch was known to the Greeks till after the age of Alexander. Indeed, the want of a name for it in a language so generally copious as the Greek, suffices to show that they were unacquainted with it. It was most probably in much earlier use in Italy. The words ϑολος, αψις, and ψαλις, are not used in a sense that signifies an arch until after the reign of the above-named monarch; nor is any description extant from which may be conceived the construction of an arch on scientific principles.

177. From the time of Pericles to that of Alexander, all the arts, and most especially that of architecture, seem to have attained a high state of perfection. Every moral and physical cause had concurred in so advancing them. But perfection, when once reached in the works of man, is only the commencement of their falling away from it. Liberty, the love of country, ambition in every department of life, had made Athens the focus of the arts and sciences: the defeat of the Persians at Marathon and other celebrated victories had brought peace to the whole of the states of Greece. In the space of time preceding the Peloponnesian war, there seems to have been, as it were, an explosion of every species of talent, and it was at this period that they set about rebuilding the temples and other edifices that the Persians had thrown down, of which a wise policy had preserved the ruins, so that the contemplation of desolation and misfortune afforded them an eloquent reminiscence of the peril in which they continually stood. It was indeed only after the flight of the general of Xerxes, and the victory gained by Themistocles, that a general restoration of their monuments and the rebuilding of Athens were set about. These were the true trophies of the battle of Salamis. About 335 years B.C. Alexander became master of Greece. Fired with every species of glory, and jealous of leaving to posterity monuments that should be unworthy of his greatness and fame, or other than proofs of the refinement of his taste, this prince gave a new impulse to genius by the exclusive choice that he made of the most skilful artists, and by the liberal rewards he bestowed upon them. The sacking of Corinth by the Romans in less than two centuries (about 146 B.C.) was the first disaster that the fine arts encountered in Greece; their overthrow there was soon afterwards completed by the country becoming a Roman province. At the former occurrence Polybius

(cited by Strabo) says, that during the plunder the Roman soldiers were seen casting their dice on the celebrated picture of Bacchus by Aristides. Juvenal well describes such a scene (*Satire* xi. 100.): —

> Tunc rudis et Graias mirari nescius artes,
> Urbibus eversis, prædarum in parte reperta
> Magnorum artificûm frangebat pocula miles.

The well-known story of the consul Mummius shows either that the higher ranks among the Roman citizens were not very much enlightened on the arts, or that he was a singular blockhead. We have now arrived at the period at which Greece was despoiled and Rome enriched, and must pursue the history of the art among the Romans; incidental to which a short digression will be necessary on Etruscan architecture.

Sect. XII.

ETRUSCAN ARCHITECTURE.

178. The inhabitants of Etruria, a country of Italy, now called Tuscany, are supposed to have been a colony from Greece. They certainly may have been a swarm from the original hive (see *Druidical, Celtic,* 13.; and *Cyclopean Architecture,* 32.) that passed through Greece in their way to Italy. The few remains of their buildings still existing show, from their construction, that they are coeval with the walls of Tiryns, Mycenæ (*figs.* 9. and 10.), and other works of a very early age; and it is our own opinion that the wandering from that great central nation, of which we have already so much spoken, was as likely to conduct the Etrurians at once to the spot on which they settled, as to bring them through Greece to the place of their settlement. It is equally our opinion that, so far from the country whereof we now treat having received their arts from the Greeks, it is quite as possible, and even likely, that the Greeks may have received their arts from the Etruscans. The history of Etruria, if we consult the different writers who have mentioned it, is such a mass of contradiction and obscurity, that there is no sure guide for us. It seems to be a moving picture of constant emigration and re-emigration between the inhabitants of Greece and Italy. The only point upon which we can surely rest is, that there were many ancient relations between the two countries, and that in after times the dominion of the Etruscans extended to that part of Italy which, when it became occupied by Grecian colonies, took the name of Magna Græcia. The continual intercourse between the two countries lessens our surprise at the great similarity in their mythology, in their religious tenets, and in their early works of art. We are quite aware that the learned Lanzi was of opinion (*Saggio di Lingua Etrusca*), that the Etruscans were not the most ancient people of Italy. We are not about to dispute that point. He draws his conclusion from language; we draw our own from a comparison of the masonry employed in both nations, from the remains whereof we should, if there be a difference, assign the earliest date to that of Hetruria. This, to be sure, leaves open the question whether the country was preoccupied; one which, for our purpose, it is not necessary to settle. We have Winkelman and Guarnacci on our side, who from medals and coins arrived at the belief that among the Etruscans the arts were more advanced at a very early age than among the Greeks; and Dr. Clarke's reasoning tends to prove for them a Phœnician origin.

179. Great solidity of construction is the prominent feature in Etruscan architecture. Their cities were surrounded by walls consisting of enormous blocks of stone, and usually very high. Remains of them are still to be seen at Volterra (*fig.* 108.), Cortona, Fiesole (*fig.* 109.), &c. "Mœnibus," says Alberti (*De Re Ædific.* lib. vii. c. 2.) "veterum præsertim populi Etruriæ quadratum eumdemque vastissimum lapidem probavêre." In the walls of Cortona some of the stones are upwards of 22 Roman feet in length, and from 5 to 6 ft. high, and in them neither cramps nor cement appear to have been employed. The walls of Volterra are built after the same gigantic fashion. In the earliest specimens of walling, the blocks of stone were of an irregular polygonal form, and so disposed as that all their sides were in close contact with one another. Of this species is the wall at Cora, near Velletri. The gates were very simple, and built of stones of an oblong square form. The gate of Hercules, at Volterra, is an arch consisting of nineteen stones; a

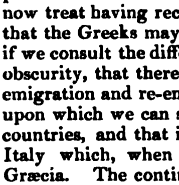


Fig. 108. WALL AT VOLTERRA.

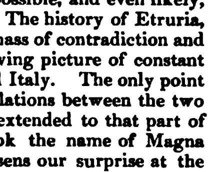


Fig. 109. WALL AT FIESOLE.

circumstance which, if its antiquity be allowed to be only of a moderately remote period, would go far to disprove all Lanzi's reasoning, for, as we have noticed in the preceding article, the arch was unknown in Greece till after the time of Alexander. According to Gori (*Museum Etruscum*), vestiges of theatres have been discovered among the ruins of some of their cities. That they were acquainted with the method of conducting theatrical representations is evident from Livy, who mentions an occasion on which comedians were brought from Etruria to Rome, whose inhabitants at the time in question were only accustomed to the games of the circus. The gladiatorial sports, which were afterwards so much the delight of the Romans, were also borrowed from the same people. They constructed their temples peripterally; the pediments of them were decorated with statues, quadrigæ, and bassi rilievi, in terra cotta, many whereof were remaining in the time of Vitruvius and Pliny. Though it is supposed that the Etruscans made use of wood in the entablatures of their temples, it is not to be inferred that at even the earliest period they were unacquainted with the use of stone for their architraves and lintels, as is sufficiently proved in the Piscina of Volterra.

180. The Romans, until the conquest of Greece, borrowed the taste of their architecture from Etruria. Even to the time of Augustus, the species called Tuscan was to be seen by the side of the acclimatised temple of the Greeks.

181. The *atrium* or court, in private houses, seems to have been an invention of the Etruscans.. Festus derives its name from its having been first used at Atria, in Etruria: "Dictum Atrium quia id genus edificii primum Atriæ in Etruria sit institutum." We shall, however, allude in the next section to Etruscan architecture as connected with Roman; merely adding here, that in about a year after the death of Alexander the nation fell under the dominion of the Romans.

Sect. XIII.

ROMAN ARCHITECTURE.

182. The Romans can scarcely be said to have had an original architecture; they had rather a modification of that of the Greeks. Their first instruction in the art was received from the Etruscans, which was probably not until the time of the Tarquins, when their edifices began to be constructed after fixed principles, and to receive appropriate decoration. In the time of the first Tarquin, who was a native of Etruria, much had been done towards the improvement of Rome. He brought from his native country a taste for that grandeur and solidity which prevailed in the Etruscan works. After many victories he had the honour of a triumph, and applied the wealth he had acquired from the conquered cities to building a circus, for which a situation was chosen in the valley which reached from the Aventine to the Palatine Hill. Under his reign the city was fortified, cleansed, and beautified. The walls were built of hewn stone, and the low grounds about the Forum drained, which prepared the way for the second Tarquin to construct that Cloaca Maxima, which was reckoned among the wonders of the world. The Forum was surrounded with galleries by him; and his reign was further distinguished by the erection of temples, schools for both sexes, and halls for the administration of public justice. This, according to the best chronologies, must have been upwards of 610 years B. C. Servius Tullius enlarged the city, and among his other works continued those of the temple of Jupiter Capitolinus, which had been commenced by his predecessor; but the operations of both were eclipsed by monuments, for which the Romans were indebted to Tarquinius Superbus, the seventh king of Rome. Under him the Circus was completed, and the most effective methods taken to finish the Cloaca Maxima. This work, on which neither labour nor expense was spared to make the work everlasting, is of wrought stone, and its height and breadth are so considerable, that a cart loaded with hay could pass through it. Hills and rocks were cut through for the purpose of passing the filth of the city into the Tiber. Pliny calls the Cloacæ, "operum omnium dictu maximum, suffossis montibus, atque urbe pensili, subterque navigatâ." The temple of Jupiter Capitolinus was not finished till after the expulsion of the kings, 508 B. C.; but under Tarquinius Superbus it was considerably advanced. In the third consulship of Poplicola, the temple was consecrated. As the name, which was changed, imports, this temple stood on the Mons Capitolinus, and embraced, according to Plutarch, four acres of ground. It was twice afterwards destroyed, and twice rebuilt on the same foundations. Vespasian, at a late period, rebuilt it; and upon the destruction of this last by fire, Domitian raised the most splendid of all, in which the gilding alone cost 12,000 talents. It is impossible now to trace the architecture of the Romans through its various steps between the time of the last king, 508 B. C., and the subjugation of Greece by that people in the year 145 B. C., a period of 363 years. The

disputes in which they were continually engaged left them little leisure for the arts of peace; yet the few monuments with which we are acquainted show a power and skill that mark them as an extraordinary race. Thus in the year 397 B. C., on the occasion of the siege of Veii, the prodigy, as it was supposed, of the lake of Alba overflowing, when there was little water in the neighbouring rivers, springs, and marshes, induced the authorities to make an *emissarium*, or outlet for the superfluous water, which subsists to this day. The water of the lake Albano, which runs along Castel Gondolfo, still passes through it. A few years after this event an opportunity was afforded, which, with more care on the part of the authorities, might have considerably improved it, after its demolition by Brennus. This event occurred 389 B. C., and was nearly the occasion of the population being removed to Veii altogether, a place which offered them a spot fortified by art and nature, good houses ready built, a wholesome air, and a fruitful territory. The eloquence, however, of Camillus prevailed over their despondency. Livy (b. vi.) observes, that in the rebuilding, the state furnished tiles, and the people were allowed to take stone and other materials wherever they could find them, giving security to finish their houses within the year. But the haste with which they went to work caused many encroachments on each other's soil. Every one raised his house where he found a vacant space; so that in many cases they built over the common sewers, which before ran under the streets. So little taste for regularity and beauty was observed, that the city, when rebuilt, was even less regular than in the time of Romulus; and though in the time of Augustus, when Rome had become the capital of the world, the temples, palaces, and private houses were more magnificent than before, yet these decorations could not rectify the fault of the plan. Though perhaps not strictly within our own province, we may here mention the temple built in honour of Juno Moneta, in consequence of a vow of L. Furius Camillus when before the Volsci. This was one of the temples on the Capitoline hill. The epithet above mentioned was given to the queen of the gods, a short time before the taking of Rome by the Gauls. It was pretended that from the temple of Juno a voice had proceeded, accompanied with an earthquake, and that the voice had admonished the Romans to avert the evils that threatened them by sacrificing a sow with pig. She was hence called *Moneta* (from monere). The temple of Juno Moneta becoming afterwards a public mint, the medals stamped in it for the current coin took the name of Moneta (money). This temple was erected about 345 years B.C., on the spot where the house of Marcus Manlius had stood.

183. In the time that Appius Claudius was censor, about 309 B. C., the earliest paved road was made by the Romans. It was first carried to Capua, and afterwards continued to Brundusium, a length altogether of 350 miles. Statius calls it *regina viarum*. Paved with the hardest stone, it remains entire to the present day. Its breadth is about 14 ft.; the stones of which it is composed vary in size, but so admirably was it put together that they are like one stone. Its bed is on two strata; the first of rough stones cemented with mortar, and the second of gravel, the thickness altogether being about 3 ft. To the same Appius Claudius belongs the honour of having raised the first aqueduct. The water with which it supplied the city was collected from the neighbourhood of Frascati, about 100 ft. above the level of Rome. The Romans at this time were fast advancing in the arts and sciences; for in about nineteen years afterwards we find Papirius, after his victory over the Samnites, built a temple to Quirinus out of a portion of its spoils. Upon this temple was fixed (*Pliny*, b. vii. c. 60.) the first sun-dial that Rome ever saw. For a long while the Romans marked only the rising and setting of the sun; they afterwards observed, but in a rude clumsy manner, the hour of noon. When the sun's rays appeared between the rostra and the house appointed for the reception of the ambassadors, a herald of one of the consuls proclaimed with a loud voice that it was mid-day. With the aid of the dial they now marked the hours of the day, as they soon after did those of the night by the aid of the clepsydra or water-clock. The materials for carrying on the investigation are so scanty, and moreover, as in the case of Grecian architecture, without examples whereon we can reason, that we will not detain the reader with further speculations, but at once proceed to that period (145 B.C.) when Greece was reduced to a Roman province. Art, in the strict application of that word, was not properly understood by the victorious Romans; and a barrenness appears to have clung about that whereof we treat, even with all the advantages that Rome possessed. It may be supposed that the impulse given to the arts would have been immediate; but, like the waves generated by the ocean storm, a succession of them was necessary before the billows would approach the coast. Perhaps, though it be only conjectural, the first effect was visible in the temple reared to Minerva at Rome, out of the spoils of the Mithridatic war, by Pompey the Great, about sixty years B.C., after a triumph unparalleled perhaps in the history of the world; after the conclusion of a war of thirty years' duration, in which upwards of two millions of his fellow-creatures had been slain and vanquished; after 846 ships had been sunk or taken, and 1538 towns and fortresses had been reduced to the power of the empire, and all the countries between the lake Mæotis and the Red Sea had been subdued. It is to be regretted that no remains of this temple exist. The inscription (*Plin.* lib. vii. c. 26.) was as follows: —

CN . POMPEIUS . CN . F . MAGNUS . IMP .
BELLO . XXX . ANNORUM . CONFECTO .
FUSIS . FUGATIS . OCCISIS . IN . DEDITIONEM . ACCEPTIS .
HOMINUM . CENTIES . VICIES . SEMEL . CENTENIS .
LXXXIII . M .
DEPRESSIS . AUT . CAPT . NAVIBUS . DCCCXLVI
OPPIDIS . CASTELLIS . MDXXXVIII
IN . FIDEM . RECEPTIS .
TERRIS . A . MAEOTI . LACU . AD . RUBRUM . MARE
SUBACTIS .
VOTUM . MERITO . MINERVÆ .

184. The villas of the Romans at this period were of considerable extent; the statues of Greece had been acquired for their decoration, and every luxury in the way of decoration that the age could afford had been poured into them from the plentiful supply that Greek art afforded. To such an extreme was carried the determination to possess every thing that talent could supply, that we find Cicero was in the habit of employing two architects, Chrysippus and Cluatius (*ad Atticum*, lib. iii. epist. 29. and lib. xii. epist. 18.); the first certainly, the last probably a Greek. Their extent would scarcely be credited but for the corroboration we have of it in some of their ruins.

185. Until the time of Pompey no permanent theatre existed in Rome: the ancient discipline requiring that the theatre should continue no longer than the shows lasted. The most splendid temporary theatre was that of M. Æmilius Scaurus, who, when ædile, erected one capable of containing 80,000 persons, which was decorated, from all accounts, with singular magnificence and at an amazing cost. History (*Plin.* xxxvi. 15.) records an extraordinary instance of mechanical skill, in the theatre erected by Curio, one of Cæsar's partisans, at the funeral exhibition in honour of his father. Two large theatres of timber were constructed back to back, and on one side so connected with hinges and machinery for the purpose that when the theatrical exhibitions had closed they were wheeled or slung round so as to form an amphitheatre, wherein, in the afternoon, shows of gladiators were given. Returning, however, to the theatre erected by Pompey, which, to avoid the animadversion of the censors, he dedicated as a temple to Venus: the plan (*Pliny*, vii. 3.) was taken from that at Mitylene, but so enlarged as to be capable of containing 40,000 persons. Round it was a portico for shelter in case of bad weather: a curia or senate house was attached to it with a basilica or hall for the administration of justice. The statues of male and female persons celebrated for their lives and characters were selected and placed in it by Atticus, for his attention to which Cicero (*Epist. ad Attic.* iv. 9.) was commissioned by Pompey to convey his thanks. The temple of Venus, which was attached to avoid the breach of the laws committed, was so contrived that the seats of the theatre served as steps to the temple; a contrivance which also served to escape the reproach of encountering so vast an expense for mere luxury, for the temple was so placed that those who visited the theatre might seem at the same time to come for the purpose of worshipping the goddess. At the solemnity of its dedication the people were entertained with the most magnificent shows that had ever been exhibited in Rome. We cannot prolong the account of this edifice by detailing them,—indeed that would be foreign to our purpose; but we may add, that such a building presents to us a genuine idea of the vast grandeur and wealth of those principal subjects of Rome, who from their own private revenues could rear such magnificent buildings, and provide for the entertainment of the people shows to which all the quarters of the globe contributed, and which no monarch now on earth could afford to exhibit. This theatre was finished about 54 B.C.

186. In the year 45 B.C. Rome witnessed a triumph not less extraordinary than that we have just recorded,—that of Julius Cæsar on his return from Utica. From the commencement of the civil war that had raged he had found no leisure for celebrating the triumphs which induced the people to create him dictator for ten years, and to place his statue in the Capitol opposite to that of Jupiter, with the globe of the earth under his feet, and the inscription "To Cæsar the Demi-God." We need scarcely remind our readers that his first triumph was over the Gauls; that this was followed by that over Ptolemy and Egypt; the third over Pharnaces and Pontus; and the fourth over Juba. The triumph recorded these appropriately; but we leave that—merely observing, by the way, that the fruit of his victories amounted to 65,000 talents and 2822 crowns of gold, weighing together 20,414 Roman pounds,—to state that on this occasion the Circus was enlarged, a lake sunk for the exhibition of Egyptian and Tyrian galleys, and that in the same year he dedicated a temple to Venus Genetrix, and opened his new forum. Warriors are not often inclined to call in the aid of the arts, except for commemorating their own actions. Not so with Cæsar. In the year 44 B.C., after his triumph over the sons of Pompey, we once more find him engaged in the arts of peace. A temple to Clemency was erected by him, in which his statue was placed near to that of the goddess, and joining hands with her. In the next year he laid

the foundations of what at the time were considered two magnificent edifices for the ornament of the city: a temple to Venus, which for grandeur it is supposed would have surpassed every example of that kind in the world; and a theatre of very gigantic dimensions, —both which were afterwards completed by Augustus. But the projects he conceived were only equalled by those of Alexander. He began the rebuilding and repair of many towns in Italy; the drainage of the Pontine marshes, the malaria of which is the curse of Rome to the present day; the formation of a new bed for the Tiber from Rome to the sea, for the purpose of improving the navigation of that river; the formation of a port at Ostia for the reception of first-rate ships; a causeway over the Apennines from the Adriatic to Rome; the rebuilding of Corinth and Carthage, whither colonies had been sent by him, a scheme afterwards perfected by Augustus; a canal through the Isthmus of Corinth to avoid the navigation round the Peloponnesus; and lastly, the formation of an exact geographical map of the Roman empire, with the roads marked thereon, and the distances of the towns from each other. Such was Cæsar, whom to eulogise would be impertinent.

187. Augustus deprived the Romans of their liberty, and in return for the deprivation consoled them with all the gratification the arts could supply. The victorious Romans had known little of the arts in their highest state of refinement, and the degraded Greeks were constrained to neglect them. They were in a state of barrenness during a portion of the last age of the Roman republic; nor did they exhibit any signs of fruitfulness until Cæsar had established the empire on the ruins of the expiring republic, and his successor, giving peace to the universe, closed the temple of Janus, and opened that of the arts. By him skilful artists, pupils of the great masters, were invited from Greece, where, though languishing, they were yet silently working without fame or encouragement. Some who had been led into slavery, like Rachel of old, carried their gods with them — the gods of the arts. Encouraged by the rising taste of their masters, they now began to develop the powers they possessed, and their productions became necessary to the gratification of the people. Thus it was that our art, among the others, born and reared in Greece, made Italy its adopted country, and there shone with undiminished splendour, though perhaps less happy and less durable. Though the exotic might have lost some beauties in the soil to which it was transplanted, the stock possessed such extraordinary vigour that grafts from it still continue to be propagated in every quarter of the globe.

188. The Greek architects who settled in Italy executed works of surprising beauty: they raised up pupils, and founded a school. It must be conceded that it was more an imitative than an original school, wherein it was necessary to engraft Roman taste which was modified by different habits and climate, on Greek art. And here we cannot refrain from an observation or two upon the practice in these days of comparing Greek and Roman architecture. Each was suitable to the nation that used it; the forms of Greek columns, their intercolumninations, the inclination of the pediment, were necessarily changed in a country lying between four and five degrees further north from the equator. But the superficial writers, whose knowledge occasionally appears to instruct the world, never take these matters into their consideration; and we regret, indeed, to admit that in this country the philosophy of the art is little understood by the public, from the professors being generally too much engaged in its practice to afford them leisure for diffusing the knowledge they possess.

189. The Romans were trained to arms from their cradle; and that they were very averse to the cultivation of the arts by their youth, the passage in the *Æneid* (b. vi. v. 847.), which has been so often quoted, is a sufficient proof: —

> Excudent alii spirantia mollius æra
> Credo equidem; vivos ducent e marmore vultus.
> * * * * * *
> Tu regere imperio populos, Romane, memento;
> Hæ tibi erunt artes.

190. They were at all times anxious to subjugate for their own purposes those nations that successfully cultivated the arts; a motive which, joined to the desire of aggrandisement, induced them at a very early period to carry their arms against the Etruscans, who were in a far higher state of cultivation than themselves. This was also one motive to their conduct in Sicily and Asia Minor; whence, as well as from Greece, they drew supplies of artists for Rome, instead of employing their own citizens. Though in Rome architecture lost in simplicity, it gained in magnificence. It there took deeper root than the other arts, from its affording, by the dimensions of its monuments, more splendour to the character of so dominating a nation. Its forms are more susceptible of real grandeur than those of the other arts, which are put in juxtaposition with nature herself; and hence they were more in keeping with the politics of the people. The patronage of the fine arts by Augustus has never before or since been equalled. They followed his good fortune, they dwelt in the palace, and sat on the throne with him. His boast was not a vain one, when he asserted that he found his capital built of brick and left it of marble. By him was reared in the capital in question the temple and forum of Mars the Avenger; the temple of Jupiter

Tonans, on the Capitol; that of Apollo Palatine, with public libraries; the portico and basilica of Caius and Lucius; the porticoes of Livia and Octavia; and the theatre of Marcellus. "The example," says Gibbon, "of the sovereign was imitated by his ministers and generals; and his friend Agrippa left behind him the immortal monument of the Pantheon."

191. Under Tiberius and Caligula architecture seems to have been in a state of languor, nor do we know of any thing in the reign of Claudius the fifth Cæsar, save the completion of one of the finest aqueducts of Rome, that of *Aqua Claudia*, whose length is 46 m., in more than ten whereof the water passes over arches raised more than 100 ft. from the surface of the ground. Nero's reign, though his taste bordered more on show than intrinsic beauty, was on the whole favourable to architecture. Much could not be expected of a man who covered with gilding a statue of Alexander, and decapitated fine statues for the purpose of substituting his own head for that of the original. The colossal statues of himself which he caused to be sculptured indicate a mind prone to vice and excess. The same taste for exaggeration was carried into his buildings. His prodigality in every way was inexhaustible; he seems rather to have left monuments of expenditure than of taste. A palace, which from its extraordinary richness has been called the *Domus Aurea*, was erected for him by his architects Severus and Celer, than which nothing could be more brilliant nor gorgeous; beyond it no pomp of decoration could be conceived. In the midst of so much wealth the only object of contempt was its possessor. The reader may form some notion of it when told (*Plin.* lib. xxxvi.) that in finishing a part of it Otho laid out a sum equivalent to near 404,000*l.* sterling.

192. Galba, Otho, and Vitellius can scarcely be said to have reigned. It was reserved for Vespasian and his son Titus, the tenth and eleventh Cæsars, to astonish the city, and indeed the world, by such masses of building in amphitheatres and baths as we may predict it will never again see reared. The Coliseum (*fig.* 110.), so named, according to some, from its gigantic dimensions, but according to others, with more probability, from its proximity to a colossal statue of Nero, was commenced by the father, and finished by the son. According to Justus Lipsius, the seats would hold 87,000 persons; to this number Fontana adds 10,000, which the upper porticoes would contain, and 12,000 more in other parts; making a total of 109,000 spectators who could view at their ease the sports and combats in the arena. We do not think there is much, if any, exaggeration in Fontana's statement, seeing that the building covers nearly six English acres of ground. The reader will from the above description identify the structure mentioned by Martial:—

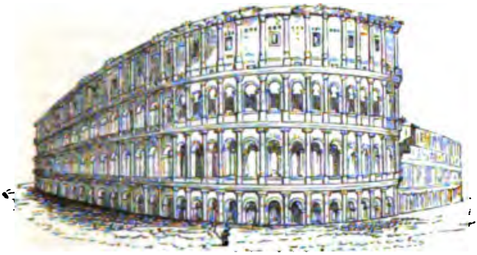


Fig. 110. THE COLISEUM.

> Omnis Cæsareo cedat labor amphitheatro,
> Unum pro cunctis fama loquatur opus.

"Biennio post ac menses novem amphitheatri perfecto opere," is the expression of Victor in respect to the time employed in its construction. Though the monument itself be astonishing, still more so is it that such a mass should have taken only two years and nine months in building, even with all the means that the emperors had under their power. We shall reserve a more particular description of it for a subsequent page. In spite of the ravages of time, and the hands, ancient and modern, which have despoiled it for its materials, enough still remains completely to exhibit the original plan, and to enable the spectator to form a perfect idea of the immense mass. The Baths of Titus were another of the wonders of the age. The remains of them are not so perfect as others, but they are still majestic. Besides the edifices erected by Vespasian and his son, they made it a part of their duty to take measures for the preservation of those which existed, and were in need of repair and restoration.

193. The last Cæsar, Domitian, was of a disposition too wicked to be of service to his country: his reign was, fortunately for it, but short. In the year 98, on the death of Nerva, Trajan became master of the empire. He had served against the Jews under Vespasian and Titus, and probably acquired from them and their example a great taste for architecture, in which he shed a lustre upon the country as great as his splendid victories over the Persians and Dacians gained for it in the field. Of his works, which, as Gibbon says, bear the stamp of his genius, his bridge over the Danube must have been a surprising effort. According to Dio Cassius, this bridge was constructed with twenty stone piers in

the river, 150 ft. high and 60 feet wide, bearing arches of 170 ft. span. It was destroyed by Hadrian, his successor: some say out of envy; but the plea was, that it served the barbarians as an inlet to the empire, as much as it facilitated the passage of its troops to keep them in subjection. His triumphal arches, his column (*fig.* 111.), and forum, and other works, attest the vigour and beauty of the art under the reign of Trajan. The forum was a quadrangle surrounded by a lofty portico, into which the entrance was through four triumphal arches, and in the centre was the column. Apollodorus was his principal architect, by whom was erected the column above mentioned, which was not only the chef-d'œuvre of the age, but has never been surpassed. It is 110 ft. high, thus marking the height of the hill that had been cut away to receive the forum. "The public monuments with which Hadrian adorned every province of the empire were executed not only by his orders, but under his immediate inspection. He was himself an artist; and he loved the arts, as they conduced to the glory of the monarch. They were encouraged by the Antonines, as they contributed to the happiness of the people. But if they were the first, they were not the only architects of their dominions. Their example was universally imitated by their principal subjects, who were not afraid of declaring to the world that they had spirit to conceive and wealth to accomplish the noblest undertakings. Scarcely had the proud structure of the Coliseum been dedicated at Rome, before edifices of a smaller scale indeed, but of the same design and materials, were erected for the use and at the expense of the cities of Capua and Verona. The inscription of the stupendous bridge at Alcantara attests that it was thrown over the Tagus by the contribution of a few Lusitanian communities. When Pliny was entrusted with the government of Bithynia and Pontus, provinces by no means the richest or most considerable of the empire, he found the cities within his jurisdiction striving with each other in every useful and ornamental work that might deserve the curiosity of strangers, or the gratitude of their citizens. It was the duty of the proconsul to supply their deficiencies, to direct their taste, and sometimes to moderate their emulation. The opulent senators of Rome and the provinces esteemed it an honour, and almost an obligation, to adorn the splendour of their age and country; and the influence of fashion very frequently supplied the want of taste or generosity. Among a crowd of these private benefactors, we select Herodes Atticus, an Athenian citizen, who lived in the age of the Antonines. Whatever might be the motive of his conduct, his magnificence would have been worthy of the greatest kings." We make no apology for so long a quotation from the historian of the *Decline and Fall*, whose expressions are so suitable to our purpose. The family of Herod was highly descended; but his grandfather had suffered by the hands of justice; and Julius Atticus, his father, must have died in poverty, but for the discovery of an immense treasure in an old house, the only piece of his patrimony that remained. By the law this would have been the property of the emperor, to whom Julius gave immediate information. Nerva the Just, who was then on the throne, refused to accept it, desiring him to keep it and use it. The cautious Athenian hesitatingly replied, that the treasure was too large for a subject, and that he knew not how to *use it*. The emperor replied, "*Abuse it then*, for 'tis your own." He seems really to have followed the monarch's bidding, for he expended the greatest part of it in the service of the public. This man's son, Herodes, had acquired the prefecture of the free cities of Asia, among which the town of Troas being ill supplied with water, he obtained from the munificence of Hadrian a sum equivalent to 100,000*l.* sterling for constructing a new aqueduct. The work on execution amounted to double the estimate; and on the officers of the revenue complaining, Atticus charged himself with the whole of the additional expense. Some considerable ruins still preserve the fame of his taste and munificence. The Stadium which he erected at Athens was 600 ft. in length, entirely of white marble, and capable of receiving the whole body of the people. To the memory of his wife, Regilla, he dedicated a theatre, in which no wood except cedar was employed. He restored the Odeum to its ancient beauty and magnificence. His boundless liberality was not, however, confined within the city of Athens. "The most splendid ornaments," says Gibbon, "bestowed on the temple of Neptune in the Isthmus, a theatre at Corinth, a stadium at Delphi, a bath at Thermopylæ, and an aqueduct at Canusium in Italy, were insufficient to exhaust his treasures. The people of Epirus, Thessaly, Eubœa, Bœotia, and Peloponnesus experienced his favours, and many inscriptions of the cities of Greece and Asia gratefully style Herodes Atticus their patron and benefactor."

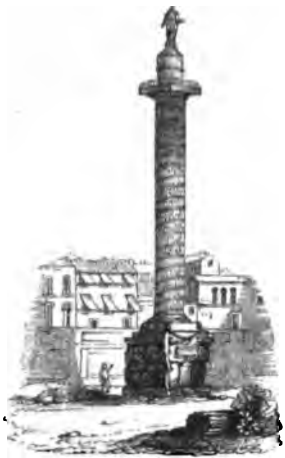


Fig. 111. COLUMN OF TRAJAN.

194. Architecture was still practised with success under the Antonines, the successors of Hadrian, among whom Marcus Aurelius was a great patron of the arts. On these history almost instructs us, that the effect of the individual character of the sovereign, and the general and leading circumstances of his reign, are so influential as to enable us from the two last to estimate the prosperity of the first.

195. The rapidity with which after the time of Commodus, that most unworthy son of a worthy father, the emperors succeeded each other, was as unfavourable for the arts as for their country. A little stand was made against their rapid decline, under Septimius Severus, whose triumphal arch still remains as a link in the chain of their decay, and perhaps the first. It is difficult to conceive how in so short a period from the time of Marcus Aurelius, not thirty years, sculpture had so lost ground. In the arch commonly called that of the Goldsmiths, the form and character of good architecture is entirely obliterated. Its profiles are vicious, and its ornaments debased and overcharged.

196. The art was somewhat resuscitated under Alexander Severus, but it was fast following the fate of the empire in the West, and had become almost lifeless under Valerian and his son Gallienus, whose arch is an index to its state in his reign. The number of competitors for the purple, and the incursions of the barbarians, were felt. Aurelian and Probus suspended its total annihilation; but their reigns were unfortunately too short to do it substantial service. The extraordinary structures at Baalbec and Palmyra have been referred, on the authority of a fragment of John of Antioch, surnamed Malala, to the age of Antoninus Pius; but we are inclined to think the style places them a little later than that period. Baalbec, or, as its Syrian meaning imports, the City of Baal, or the Sun, is situate at the north-eastern extremity of the valley of Becat or Beka, near that place where the two Lebanons unite, about fifty miles to the north-west of Damascus. The first traveller who described it with accuracy was Maundrell, in his Journey from Aleppo to Jerusalem, in 1697. It has, however, been since visited, as well as Palmyra, by Messrs. Wood and Dawkins, in 1751, and by M. Volney at a later period. The principal building, the temple, is of a rectangular form, and is seated in the centre of the western extremity of a large quadrangular enclosure, two of whose sides were parallel to those of the temple; and parallel to its front was the third. To this was attached an hexagonal court, serving as a vestibule, in front of which was the grand entrance portico. The length of the quadrangle is about 360 ft. and breadth about 350 ft. (See *fig.* 112.) The temple, marked A, is, in round numbers, 200 ft. in length, and 100 ft. in breadth; it was dipteral, and had ten columns in front and nineteen on the sides. That the reader may form some idea of the style, which was to the last degree debased. and would not justify by any utility the extending this ac-

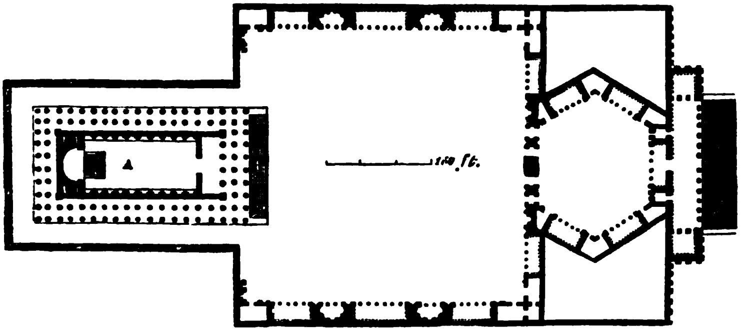


Fig. 112. PLAN OF THE TEMPLE AT BAALBEC.

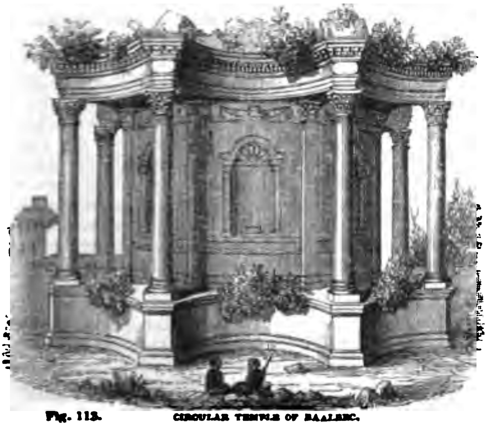


Fig. 113. CIRCULAR TEMPLE OF BAALBEC.

count, we have in *fig.* 113. given the sketch of a circular temple standing near the above. Of Emesa, the other celebrated Cœlo-Syrian city, not a vestige remains.

197. Of Tadmor, or Palmyra, denoting both in Syriac as well as Latin a multitude of palm-trees, Solomon was said to have been the original founder. It lies considerably to the east of Baalbec, and upwards of 200 miles from the nearest coast of Syria. Situate between the Roman and Parthian monarchies, it was suffered to observe a humble neutrality until after the victories of Trajan; when, sinking into the bosom of Rome, it flourished more than 150 years in the subordinate though humble rank of a colony. "It was during that peaceful period," observes Gibbon, "if we may judge from a few remaining inscriptions, that the wealthy Palmyrenians constructed those temples, palaces, and porticoes, whose ruins, scattered over an extent of several miles, have deserved the curiosity of our travellers." The ruins of it were discovered by some English travellers towards the end of the 17th century, and were more lately visited by the Messrs. Dawkins and Wood, already mentioned. The power of Zenobia, who wished to shake off the subjection to Rome, was insufficient to withstand the forces of Aurelian, and Palmyra fell into his hands about the year 237. A slight sketch of the ruins (*fig.* 114.) is here given. The style of architecture is almost the same as that of Baalbec; and, like that, so vitiated in almost every profile, that we do not think it necessary longer to dwell upon it, although great the extent of its ruins. In the same way, we must pass over those of Djerash, which were visited by Mr. Barry, and of other considerable cities, though some are said to contain examples in a better and purer style.

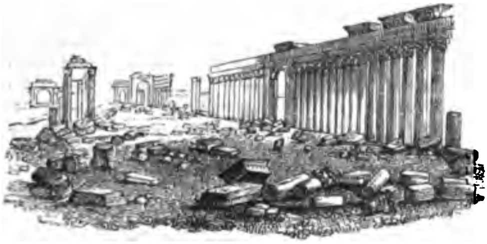


Fig. 114. RUINS OF PALMYRA.

198. The reign of Dioclesian was extended, and was illustrious from his military exploits. It was also remarkable for the wisdom he displayed in dividing with others the discharge of duties he could not himself perform; as well as, finally, by his abdication and retirement to Spalatro. Architecture was, however, too far sunk for him to raise it; and, though monuments of great grandeur were reared by him in Rome and his native town of Salona, they were degenerated by innovation and a profusion of ornaments which sometimes proved disastrous to those beneath, upon whom they occasionally fell, but the taste for which, among the Romans, had increased by their intercourse with the East. At a period when no sculptor existed in Rome, this monarch raised the celebrated baths there which bear his name. His palace at Spalatro (*fig.* 115.) covered between nine and ten English acres. Its form was quadrangular, flanked with sixteen towers. Two of the sides were 600 ft., and the other 700 ft. in length. It was constructed of stone little inferior to marble. Four streets, intersecting each other at right angles, divided the several parts of the edifice; and the approach to the principal apartment was from a stately entrance, still called the golden gate. By comparing the present remains with the Treatise by Vitruvius, there appears a coincidence in the practice here with the precepts of that author. The building consisted of only one story, and the rooms were lighted from above. Towards the south-west was a portico upwards of 500 ft. long, ornamented with painting and sculpture. We do not think it necessary to follow up further the decay of the arts in the West; it is sufficient to add that the fifth century witnessed the contemporaneous fall of them and of Rome itself.

199. Towards the year 330, the seat of the Roman empire was removed to Constantinople, where the reign of Constantine, though brilliant, was unsuccessful in restoring the arts, upon which religious as well as political causes had begun to act. The establishment of Christianity had less effect on architecture than on her sister arts. The new species of worship could be performed as well in the old as in temples of a new form, or the old columns might be employed in new edifices, in which, indeed, they were eminently serviceable; but statues of the gods were no longer wanted, and the sculptor's art was abandoned. The removal, however, of the government to the Bosphorus retarded the decline of the empire in the East. Byzantium, on whose foundations was placed the city of Constantinople, owed its origin to a colony of Megarians; and little was it to be imagined that its disasters would have closed in so glorious a termination as occurred to it. The ancient city still continued to possess some splendid productions of the schools of Asia Minor, which it almost touched, and in common with which it enjoyed the arts. Constantine profited by the circumstance, restored the monuments, and transported thither the best examples of sculpture.

200. Architecture was called in by the emperor to aid him in affording security, convenience, and pleasure to the inhabitants of the new metropolis. Vast walls surrounded the city; superb porticoes, squares of every kind, aqueducts, baths, theatres, hippodromes, obelisks,

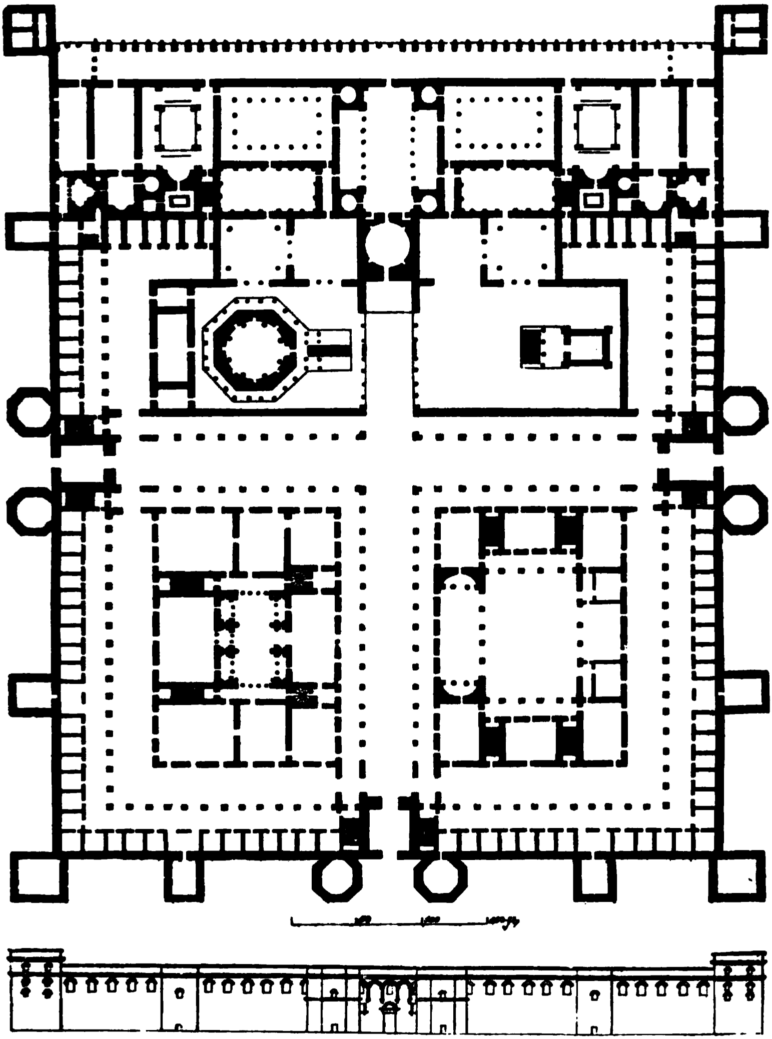


Fig. 115. PALACE OF DIOCLESIAN AT SPALATRO.

triumphal arches, stately and magnificent temples, were provided for the public. Schools of architecture, which none but persons of good birth were allowed to enter, were established, with professors and prizes for the meritorious. With all this care, one might have supposed a plentiful harvest would have been reaped. But, alas! with all the expense, with all the fine marbles that were employed, with the bronze and gold lavished on the construction and decoration of the edifices erected, the art was not re-established on its true principles. Every thing was rich; but, notwithstanding the exaggerated praises of the ignorant writers of the day, every thing was deficient in real beauty. Richness of material will never compensate for want of elegance in form. "The buildings of the new city," observes Gibbon, "were executed by such artificers as the reign of Constantine could afford; but they were decorated by the hands of the most celebrated masters of the age of Pericles and Alexander. To revive the genius of Phidias and Lysippus surpassed, indeed, the power of a Roman emperor; but the immortal productions which they had bequeathed to posterity were exposed without defence to the rapacious vanity of a despot. By his commands the cities of Greece and Asia were despoiled of their most valuable ornaments. The trophies of memorable wars, the objects of religious veneration, the most finished statues of the gods and heroes, of the sages and poets of ancient times, contributed to the splendid triumph of Constantinople, and gave occasion to the remark of the historian Cedrenus, who observes, with some enthusiasm, that nothing seemed wanting except the souls of the illustrious men whom those admirable monuments were intended to represent."

201. In Rome, the triumphal arch erected in honour of Constantine presents, to this day, an example of the barbarous and tasteless spirit of the age. It is nothing less than an incongruous mixture, in sculpture and architecture, of two periods remote from each other. But, discordant as the styles are, the absurdity of placing on it part of the triumphs of Trajan, whose arch was robbed for the occasion, is still greater. Not only was Trajan's arch despoiled of its bas reliefs, but the columns and capitals, which the architect, from ignorance, scarcely knew how to put together, were stolen for the occasion. We have used the term ignorance of the architect, who, (if the monument were not standing, the fact could scarcely be credited,) with the finest models before his eyes, placed modillions with dentils in his imposts, and left the latter out in the cornice. We leave the subject with disgust.

202. The partition of the empire at the death of Constantine was injurious as well to the arts as to the empire; and at its reunion by Constantius in 353, he exhibited but little solicitude about their prosperity. On a visit of thirty days to Rome, he presented the city with the obelisk that now stands in front of the Basilica of S. Giovanni Laterano. It had been intended by Constantine for his new city; and, after being brought down the Nile from the Temple of the Sun at Heliopolis, was conveyed to the banks of the Tiber instead of those of the Bosphorus. After being landed about three miles from the city, it was first elevated in the Circus Maximus. This piece of granite is about 115 ft. in length.

203. Julian's name is in bad odour with the Christian world; but he ought, nevertheless, to have justice rendered to him for his administration of the affairs of the empire, his love of freedom, and his patronage of the arts. This emperor, at Constantinople, constructed some porticoes and improved the port; and, even at so remote a spot as Paris, there still remain the ruins of a palace and baths of his construction; a circumstance which should make his memory an object of respect, perhaps veneration, to the inhabitants of that city.

204. Under Valentinian and Valens the arts received little attention, though the former manifested some care for them. Gratian was entitled to a sort of negative praise for leaving the empire of the West to his brother Valentinian II., and that of the East to Theodosius; who, after the death of the former, held the sway of the whole empire, patronising architecture, and erecting many large edifices in Constantinople. After this the empire was lastingly divided. On the death of Theodosius, Arcadius succeeded him in the East, and in the West Honorius, under whom, whilst he was ingloriously enjoying the pleasures and luxuries of his palace at Ravenna, Alaric, king of the Visigoths, entered and pillaged Rome in the year 410. Honorius raised or repaired several of the Basilicæ at Rome; among them that of S. Paolo fuori le Murà; and, in honour of the two emperors, a triumphal arch was erected in the city in 406, but of this no remains are in existence.

205. After this time, for sixty years the empire of the West was in a state of distraction. Nine princes filled the throne during that period, on and off the stage, rather like actors than monarchs. But the extinction of the Roman name could be no longer protracted. In 455, Genseric, king of the Vandals, gave up Rome for pillage to his soldiers for the space of three days, and some years after, his example was followed by Ricimer. In 476, the Roman empire in the West was annihilated.

206. We have thus, in this and the preceding section, shortly traced the history of Roman architecture from its dawn among the Etruscans to the close of the regal power in Rome; and from that period to the time of its culmination under Augustus, an age of great splendour in the art, comparable even with the best days of Athens, if allowance be made for the respective habits of the nations and the climates under which they were placed. From the zenith we have followed it in its setting under Dioclesian, and after that through its crepusculum, which, in 476, was succeeded by total darkness; a darkness, however, not without meteors and coruscations which occasionally enabled us to enlighten the reader in the journey he has undertaken with us. The revolutions, however, of empires, like those of the globe on its axis, bring other dawns: such is the case with the arts, which follow those revolutions; and we shall hereafter have to record another dawn of them, which, like the light of our great luminary, had its day-spring in the east, whence came the architects of Venice and Pisa. But, before we approach that period, it will be necessary to take a cursory glance at those monuments of Rome and other places under its dominion, in which the ruins alone attest the extraordinary power and magnificence of that State, and to examine the details of their construction as respects what simply presents itself to the eye.

207. We now, therefore, proceed to a view, 1. Of the religious buildings of the Romans in quadrangular and circular temples; 2. Of their public buildings in fora, triumphal arches, bridges, aqueducts, theatres, amphitheatres, and baths and circi; 3. Of their private

houses and tombs; confining ourselves to those ruins in the city, and occasionally the provinces, which best illustrate the subject.

208. *Temples.* — 1. The quadrangular Roman temple partook very much of its Greek, or perhaps Etruscan, original; though occasionally, as in the Temple of Peace, there is a very considerable deviation from the type. But the exceptions to the general rule are very few indeed in number. The most beautiful temple of the Corinthian order that perhaps ever existed in the world was the Temple of Jupiter Stator, in the Campo Vaccino (Forum), at Rome. We adopt the name of Jupiter Stator, because by that, though its propriety cannot be now ascertained, it is generally known. Recent excavations have proved that it was an octastyle peripteral temple, with twelve columns in flank, and that the cell occupied eight columns with their intercolumniations in depth. No Greek work could surpass in elegance and beauty the profile of the Corinthian order employed in this edifice. The capital, whether we consider it in design or execution, is unparalleled. At the same time we must admit that it bears every mark of the improvements that had been effected through the medium of Greek artists. Only three columns of it remain; these are 47·65 ft. high, their lower diameter being 4·84; so that, in terms of the diameter, the columns are 9·8 diameters high. The height of the entablature is a small fraction less than one quarter the height of the column. The intercolumniations are, as nearly as possible, 1·5 diameter of the column; whence the size of the temple will be easily determined.

209. Almost at the foot of the Capitol, not far from the Temple of Jupiter Stator, stands the Corinthian Temple of Jupiter Tonans, reputed to have been built by Augustus, of which, as of the last, only three columns remain. This was an hexastyle peripteral (except on the side towards the rock) temple, 115 ft. long and 92 ft. wide, measured from outside to outside of column. The columns are 47·08 ft. high, and their lower diameter is 4·60 ft.; their height, therefore, in terms of the diameter, is very nearly 10¼ diameters. The height of the entablature is 9·77 ft., or not quite one fifth of the height of the column. The intercolumniations are 1·56 diameter. There is a tale in Suetonius, that Augustus had bells suspended round this temple for the purpose of scaring the birds away, which their agitation by the wind effected. The style of this temple is inferior to that last described, yet it is not without beauty, though we must allow the cornice is, as compared with it, deficient in effect.

210. The Temple of Mars Ultor was one of those erected by Augustus. Its profile exhibits a fine and bold example of the Corinthian order. Its whole length was about 116 ft., and its breadth about 73 ft. The cornice of the entablature is wanting. The intercolumniations are about 1½ diameter.

211. In the Campo Vaccino are the remains of a Corinthian temple, built by M. Aurelius in honour of Antoninus, his predecessor, and Faustina, the daughter of that emperor and wife of M. Aurelius. It was prostylos and hexastylos: the columns are 46·10 ft. high; the entablature 11·03 ft.; diameter of the columns 4·85 ft.; and the intercolumniations, except the centre one, which is wider thau the others, are 1½ diameter of the columns. From the above it follows that the columns are 9½ diameters high, and the entablature rather less than one fourth the height of the column. The frieze is ornamented with griffins and candelabra in a very good style of art. It is not our intention to describe more than the principal temples, with their parts, but to afford to the reader in this place a general view of the art; we shall therefore merely mention those of the Maison Carrée at Nismes, and the little edifice at Trevi, which last is erected in a very vitiated style: both are of the Corinthian order, and quadrangular in form.

212. Rome is very poor in examples of Ionic temples, the only two remaining being that of Fortuna Virilis and that of Concord; the first not very pure in its detail, and the latter in the very worst style. The Temple of Fortuna Virilis is of the species called prostyle and tetrastyle; that is, with four columns in front and seven on the sides, whereof the cell occupies four intercolumniations. The height of the columns is 27·35 ft.; the lower diameter of the columns 3·11 ft.; and the height of the entablature 6·78 ft. A peculiarity has been noticed in this example of the different centres of the ornamented members being ranged so as to fall with exactness over the axes of the columns.

213. The Temple of Concord, which is a restoration, as the inscription on it proves, of a former temple that stood on the spot, is most probably of the age of Constantine, and scarcely deserves the notice here taken of it, except as a connecting link in the chain of art. It was hexastyle and peripteral. The eight columns which remain are of red and white granite of different diameters. The bases are Attic, and without plinths, except those of the angular columns. The capitals are inelegant and clumsily sculptured. The mouldings of the architrave have been chiselled away to form a plane surface for containing the inscription. Modillions and dentils are met with in the cornice, and the frieze in the interior was sculptured. The height of the columns is 42·86 ft., and their lower diameter 4·48 ft.; so that they are about 9½ diameters high. The height of the entablature is 7·2 ft., or about one sixth of the height of the column.

214. The circular temples of Rome and its neighbourhood will next be mentioned. Two of them, that of Vesta at Rome and of the Sybil at Tivoli, of the Corinthian order, are of considerable antiquity. Their cells are cylindrical, and are supposed to have been covered with domes resting on the walls, though that is by no means certain. The Temple of Vesta is raised on three steps, whilst that of the Sybil is raised on a circular basement about five feet high. Both the cellæ are encircled about with a colonnade of the Corinthian order. The capitals of the Temple of the Sybil are extraordinary as pieces of effective art. The leaves of the capital, instead of being *appliquées* to the bell, as in other examples, are in this cut into it, and impart a magical appearance to it. The *tout ensemble* of this temple seems to have been conceived with an eye to its situation, and the order seems calculated only for the spot on which it stands (see *fig.* 116.). The circular Temple of Bacchus is of a late date. In its exterior there is nothing to remark, except that it has lost a portico at its entrance which originally belonged to it. It consists of a central circular cell, if such it may be called, surrounded by a circular aisle, the former being separated from the latter by twelve pairs of double columns, coupled in the direction of the radii of the plan; from which columns arches spring, carrying a cylindrical wall 39·36 ft. diameter, covered with a hemispherical dome 65·6 ft. high from the pavement. The aisle or corridor is 14·75 ft. wide, surrounding, as we have said, the double colonnade, from which to the exterior wall is a semicircular vault, whose sofite is 32 ft. high from the pavement. The Temple of Minerva Medica is in a very ruined state; little more than half of it is standing. It was, when perfect, of a cylindrical shape, 110 ft. in diameter; but the interior was formed into ten plane vertical faces, each whereof had a semicircular recess open towards the centre of the building. A hemispherical brick dome covered the temple, whose vertex is 113 ft. from the pavement. A semicircular wing, covered by a hemispherically formed vault, stood on each side of the building, but they are now in ruins. *Fig.* 117. shows the ruin as it was in 1816, from a memorandum we then made. A rectangular vestibule with four Corinthian columns formed the

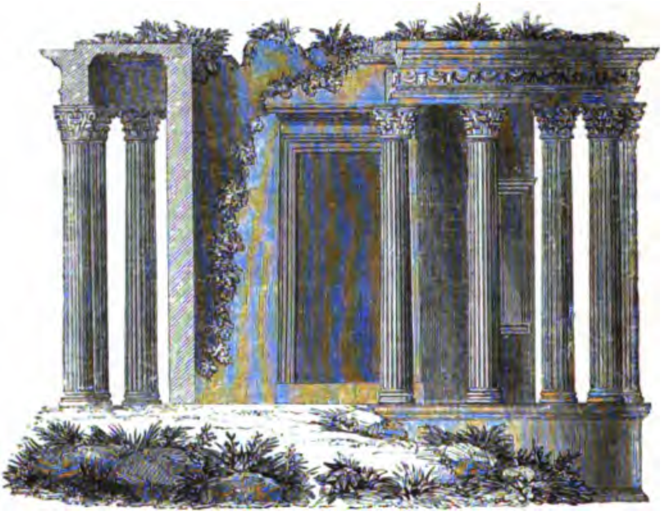


Fig. 116. TEMPLE OF THE SYBIL.

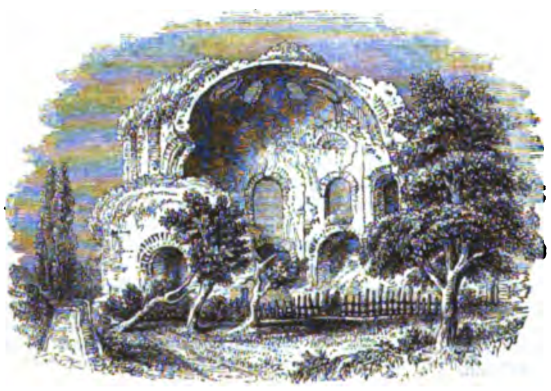


Fig. 117 TEMPLE OF MINERVA MEDICA.

entrance, and was surmounted by a pediment roof. The temple now stands in a private garden.

215. We have reserved for the last example of a circular temple the celebrated Pantheon, supposed to have formed at one time a portion of the baths of Agrippa; but whether with truth we must decline investigating, as unconnected with our present purpose. Our own belief is, that the body of the temple was erected in the time of the republic with simple large niches, as in *figs.* 118. and 119., in the left sides whereof it is shown as originally built, and on the right sides as now standing, and that the portico was appended by Agrippa about A. D. 14, at which time the columns were added to the niches, and other alterations made, as seen on the right half of the plan and section. The interior is circular, and about 139 ft. diameter, measuring from inside to inside of the columns, which are about 33 ft. high. At a height of 75 ft. from the ground in the interior springs the hemispherical dome, which has five horizontal ranks of caissons or panels, the top of the dome being terminated by what is technically termed an *eye*, or circular opening, about 27 ft. diameter. All that is found in the temple is of the Corinthian order.

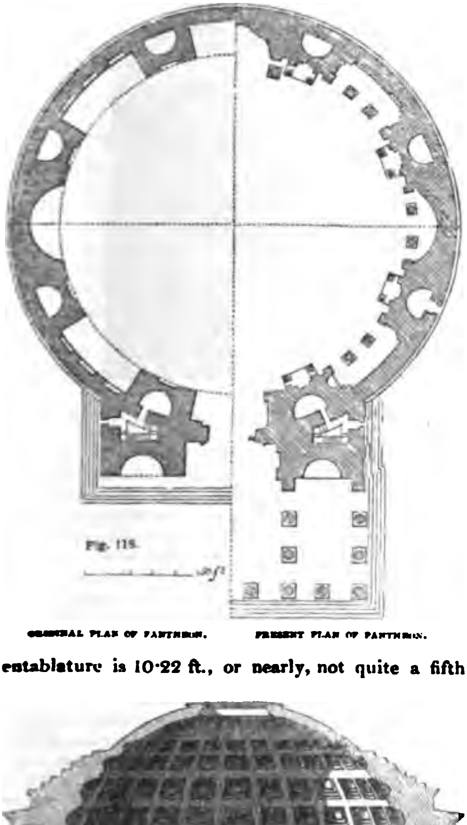


Fig. 118.

ORIGINAL PLAN OF PANTHEON. PRESENT PLAN OF PANTHEON.

(216.) *Fig.* 120. is an elevation of the Pantheon, with the portico of the Parthenon below it, for the purpose of comparing the relative sizes of the porticoes of the two buildings. The portico, it will be seen, is octastyle, and projects 62 ft. from the circumference of the circular part of the edifice. The shafts of the columns are plain, and the portico is surmounted by a pediment similar to that on the wall of the building. The columns are 47·03 ft. high, and their lower diameter 4·79 ft. The entablature is 10·22 ft., or nearly, not quite a fifth of the height of the column. The profile of the order is bold and well conceived, and the execution in a good style. It has been stripped of its ornaments, many whereof were bronze, by the cupidity of the possessors of power at various times. Though the present interior is comparatively modern, we think it right to give the following particulars of the order: — The columns are 34·67 ft. high, the lower diameter being 3·64 ft. The shafts are fluted, and have what are called *cablings* up one third of their height. It will be seen on inspection of the plan that these columns are placed in front of the great niches. We are not aware that the circumstance whereto we are about to advert has been heretofore noticed, and we give the result of our calculation in round numbers only, as an approximation to the truth. The rules for lighting apartments will form the subject of a future section. We shall here merely observe, that the contents of the building, measuring round the inner convexity of the columns, and not calculating the niches, is about 1,787,300 cubic feet, and that the area of the eye of the dome is about 32 square ft., from which it follows that 2226 cubic ft. of space in this building are lighted by 1 foot superficial of light. The building is neither gloomy nor

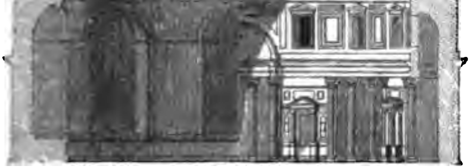


Fig. 119. SECTIONS OF ORIGINAL AND PRESENT PANTHEON.

dark; on the contrary a pleasant light is diffused throughout, and darkness is not found in any corner of it. This is a subject well worthy of consideration, and one which we propose hereafter to turn to practical account.

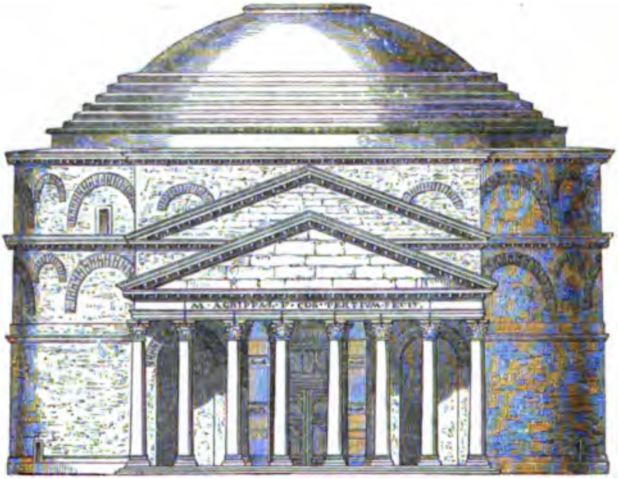


Fig. 120. ELEVATION OF PANTHEON.

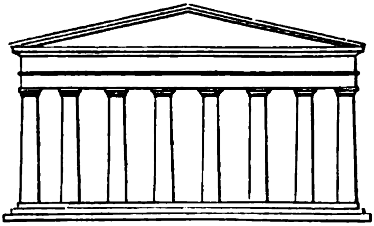


Fig. 120. PORTICO OF PARTHENON.

217. The Temple of Peace has been reserved by us to close the notices of the Roman temples, because of its deviation from the general form of other Greek and Roman temples, which in the quadrangular species are so formed on one general plan that *ab uno disce omnes* is the expression applicable to them. The *figs.* 121. and 122. represent the plan and section of this building. The former will be seen to have been rectangular, with a porch extending along the whole breadth of the building in front. This was vaulted, the summit interiorly being 35 ft. high; and in front were seven semicircular-headed apertures serving as entrances. The length of the temple outside, not including the depth of the porch, was 294 ft.; depth of the porch 30 ft.; width of the building 197 ft. The temple was longitudinally divided into three nearly equal parts, whereof the central one was a rectangular *salone* of the whole length of the temple, whose breadth was one third of its length. The roof of this was a vault with three groins, formed by the intersection of semicylindrical vaults at right angles to the central one. The height of the vaulting from the pavement was about 116 ft., and appears to have been decorated with sunk panels. We shall not however pursue the

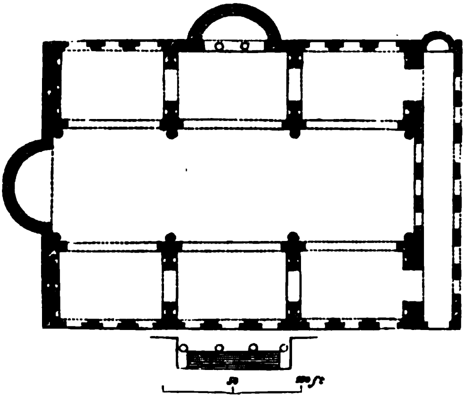


Fig. 121. PLAN OF THE TEMPLE OF PEACE.

verbal description of this edifice, which will be much better understood by an inspection of the diagrams. We will only add, that although the columns in the interior are entirely gone, and the building is in a sad state of dilapidation, enough has been discovered to prove that the restoration here submitted to the reader is not very far from the truth. In many cases the restorations of Palladio, whose works it is the fashion amongst half-instructed architects and still less informed amateurs to decry, are not to be wholly relied on in his capacity of antiquary, and certainly must not be taken for granted; but his restoration of this temple cannot widely differ from the truth. It appears to have been founded by Claudius, and finished by Vespasian after the conquest of Judea, and seems to have been the depository of the spoils of the temple at Jerusalem. It is uncertain by what accident in the reign of Commodus it was destroyed, but it is conjectured it was restored during his reign. It may not be here altogether out of place to notice that the temple in question seems in some measure to have furnished the hint for the nave of the Italian Duomo with its side aisles. It was but in the addition of the transepts and choir, whose type is indicated even in the basilicæ of the first Christians, that a variation is to be seen. If the cross, however, be not sufficiently apparent in the basilica, it cannot be mistaken in the churches but little later.

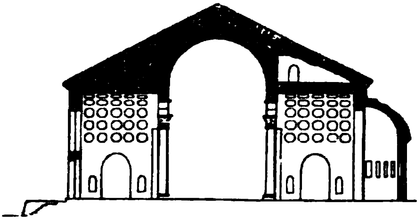


Fig. 122. TEMPLE OF PEACE.

218. *Fora.* — 2. The *Forum* of the Romans is described generally in Vitruvius (Book vi. chap. 1.). He directs that it should be a large rectangular area, whose breadth is to be about two thirds of its length. The basilica or court of justice, serving also as an exchange for the merchants, is to be attached to it. The forum in a Roman city was the arena on which business, politics, and pleasure were equally transacted, discussed, and enjoyed. Among the Greeks it was called the *αγορα*, signifying a place in which the citizens were collected. It is here to be observed, that the fora of the Romans were of two sorts: *Fora Civilia* and *Fora Venalia;* the former whereof were designed as well with the object of ornamenting the cities in which they were erected, as for admitting a site for the public courts of justice, and other public buildings; the latter were intended to provide for the necessities and conveniences of the inhabitants, and no doubt bore a resemblance to our markets. The great Forum at Rome was seated between the Palatine and Capitoline hills. Though its boundary cannot now be satisfactorily traced, there seems little doubt that it included the Arch of Septimius Severus, the Temple of Concord, and the Curia or senate house, as well as the building of the Temple of Jupiter Stator, which has been above noticed. Restorations of this have been imagined by more than one artist, and more particularly by an ingenious French artist of the name of Caristie, who has published a thin folio volume on the subject, well deserving the attention of the architectural student; but as we shall presently place before the reader a forum from Pompeii in which less uncertainty exists, we shall not stop here in our enumeration of the other fora of Rome. The Forum of Nerva is said to have been 367 ft. long, and 164 ft. wide. At one end were five arched entrances, and at the other the Temple of Nerva. The Forum of Trajan, built by the emperor whose name it bears, was erected from the foreign spoils taken by him in his wars. The coverings of its edifices were all of brass, and the porticoes and their columns constructed in an exceedingly splendid style of execution. Ammianus Marcellinus (*Hist.* lib. xvi.) describes, with much force, the delight of Constantius on contemplating it when he made his triumphal entry into Rome. The representations make its length 1150 ft., and its mean breadth about 470 ft. In it was the emperor's magnificent column (*fig.* 111.), at one end was the Temple of Trajan, and at the other his Triumphal Arch. This Forum contained the celebrated and splendid Basilica Ulpiana. The other example we shall mention was at Fano, and we mention it because it contained a basilica by Vitruvius himself. He describes the portico of the Temple of Augustus as joining that side of the basilica which was furthest from the centre of the Forum, and a temple of Jupiter as standing at the opposite end. He goes on to describe the Treasury, Prison, and Curia, as placed on the longer sides of the Forum exteriorly to the shops which surrounded the area. The commentators on Vitruvius have been at considerable pains to make out the plan of the basilica of this building from the verbal description of it by the author, — perhaps none of them with greater success than old Daniel Barbaro.

219. But no words convey the description of a place so well as a diagram of the object under consideration; and as there exists at Pompeii a forum so perfect, that all the rules given by our great master are exemplified in it, we here place the plan (*fig.* 123.) of the forum there before the reader, so that he may have a complete notion of the arrangement. Entering from the gate of Herculaneum, the principal street leads to its north-west corner,

whence the access to it is by a flight of steps downwards, through an arch in a brick wall, still partially covered with stucco. It has been conjectured with probability, that the entrances to it were occasionally closed, from the remains of iron gates having been found at some of them. A smaller passage occurs to the right of the arch just mentioned, and a fountain attached to the wall between them. A is supposed to have been a temple of Venus; B, a public granary; C, a temple of Jupiter; D, probably a Senaculum, or council chamber; E, a temple to Mercury; F, a Chalcidicum; G G, curiæ; H, treasury; I, triumphal arch; K, aræostyle portico with ambulatory above.

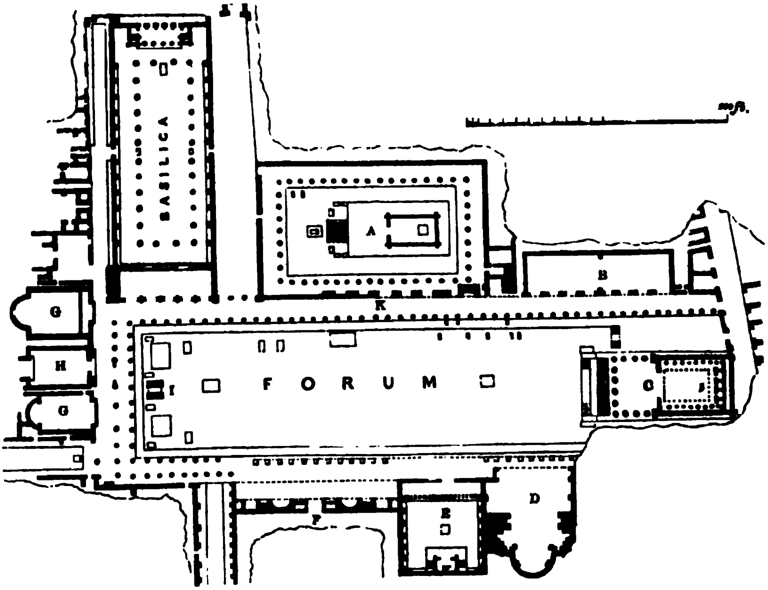


Fig. 123. FORUM OF POMPEII.

220. *Triumphal Arches.* — The Romans were the first people who erected triumphal arches; their earliest examples being extremely simple and plain. A plain arch with a statue of the victor and his trophies on the summit, was for a long period the only method practised. The arch by degrees expanded in after times, the style became enriched, and the whole was at length loaded with a profusion of every sort of ornament. Latterly they were a rectangular mass (see *fig.* 124. of the arch of Constantine), penetrated by three arches, a central and two smaller side ones. The upper part consisted of a very high attic, frequently covered with inscriptions and bas reliefs, statues, triumphal cars and ornaments of that kind. The keystones were sometimes decorated with figures of victory. Of the triumphal arches that remain there are three classes: — first, those consisting of a single arch, as the arch of Trajan at Ancona, and Titus at Rome; second, those in which there are two arches, as in the example at Verona; third, those with three arches, whereof the central was the principal one, and those at the sides much smaller, as the arches of Constantine, Septimius Severus, &c. The most ancient of the remaining arches is that of Augustus at Rimini. It was erected on the occasion of his repairing the Flaminian way from that town to Rome. The erection of these triumphal arches afforded the means of gratifying the extraordinary vanity of the people with whom they originated. Many of them are in very bad taste; a remark that applies even to the Arch of Titus, which was erected before the arts had more than begun to droop. The orders applied to them we do not think it necessary to describe in detail, because inapplicable except under precisely similar circumstances.

221. *Bridges.* — There is perhaps no single point in the history of architecture by which the civilisation of a people is so easily recognised as by that of their bridges. Latterly, in this country, the division of science as well as labour has so changed, that it seems almost necessary to refer to other works for knowledge on this subject; but as this is one in which architecture in all its branches must be considered, we shall here, as in the other sections of this work relating to the point in question, treat it in such manner as to give the reader some notion of the subject. The history of the bridges in every nation is connected with local causes, which have great influence on their construction; and though in other respects a nation may in the arts have attained a high pitch of excellence, yet it is possible that in bridge building their progress may be very limited as respects science. The matter

will depend entirely on the nature of the country. In our view of Grecian Architecture this subject has not been even mentioned. and it is nearly certain that Greece boasts no bridge whose date is anterior to its occupation by the Romans. But, independent of its want of acquaintance with the arch, the circumstance may be accounted for by the country not being intersected by any river of magnitude. Those to which one might be inclined to attach the name of river, are rather mountain torrents than sheets of water rolling their streams down to the ocean. A single arch in most cases would be all that was necessary to connect opposite banks, and the rocks themselves would form abutments for the single arch that was to connect them, without danger of failure.

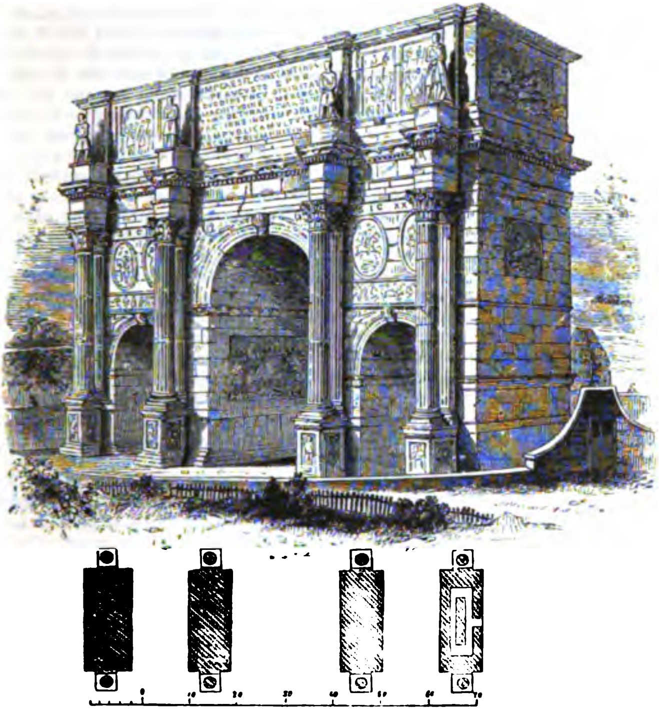


Fig. 124. PLAN AND VIEW OF THE ARCH OF CONSTANTINE.

222. In Italy, however, a country watered by many and considerable rivers, the study of the architecture of bridges was indispensable, as well for the accommodation of the cities with which it abounded, as for the service of the constant military expeditions of the restless and craving people who inhabited its surface. From its very earliest foundation, no city in the world would sooner have been placed in the predicament of requiring bridges than Rome herself; besides which, skill was required in their construction over a river like the Tiber, rapid and liable to be swelled by sudden floods. The earliest bridges of the Romans were of timber: such was that which joined the Janiculum to the Mons Aventinus, called the *Pons Sublicius* from the *sublicæ*, stakes (Liv. i. c. 33.), whereof it was composed. It is not here our intention to enumerate the ancient bridges of Rome; but the ruins of those which have come under our observation exhibit skill and science not inferior to the most extraordinary examples which modern art can exhibit; witness the Pons Narniensis on the Flaminian way near Narni, about sixty miles from Rome. It was built by Augustus, and at the present day there remains, as though standing to mock modern science, an arch of a span of 150 ft., whose intrados is 100 ft. above the level of the river below. But of the works of this kind executed by the Romans we know of none, either in ancient or modern times, that is comparable with that erected by Trajan over the Danube, whose piers from their foundation were 150 ft. in height, and the span of whose arches was 170 ft., and to the number of twenty. The bridge was 60 ft. in width. This work, whose existence is scarcely credible, putting in the background all that of which in the present day it is our habit to boast, is reputed to have been destroyed by Hadrian, the successor of its founder, under a pretence that if the barbarians became masters of it, it might serve them as well

for making incursions on the empire, as for the empire in repressing those incursions. But other less creditable motives have been attributed to Hadrian for its destruction, one of them the envy he had of the name of its founder. There are still partial remains of an ancient Roman bridge over the Tagus near Alcantara. This consisted of six arches, each 80 ft. span, extending altogether 800 ft. in length, and some of them 200 ft. high above the river. We do not, in closing our brief view of the bridges of the Romans, more than mention the extraordinary temporary bridge which Cæsar threw over the Rhine.

223. *Aqueducts.* — It is obvious that of all the requisites for a city, the supply of wholesome water is only equalled by that of discharging it, which latter we have before seen was well provided for in the Eternal City. The aqueducts by which the Romans supplied their cities with this necessary element, are among the largest and most magnificent of their works. Their ruins alone, without other testimony, supply the means of estimating their extraordinary power, skill, and industry. They are works which sink into nothingness all other remnants of antiquity, not even excluding the amphitheatres, which we shall soon have to notice, because they were for the comfort, not the pastime, of the people. The earliest aqueduct was that of Appius Claudius, which we have above noticed as constructed in the 442d year of the city. It conveyed the Aqua Appia to Rome, from a distance of between seven and eight miles, by a deep subterraneous channel upwards of eleven miles in length. We shall here digress for a moment, by observing that upon the discovery of good water at a distance from the city at a much higher level than the service therein indicated, it was the practice to supply by means of a channel raised at any height as the case needed, through a stone-formed trough raised on the tops of arches as the course of it required over valleys, and otherwise became necessary from the nature of the face of the country, such a quantity as the source would afford. Hence the arcades raised to carry this simple trough of supply were often of stupendous height, and their length was no less surprising. In the present day, the power of steam has afforded other means of supplying a great city with water; but we much question whether the supply afforded by all the concealed pipes of this vast metropolis can compete in refreshment and general utility to its inhabitants with those at the present day poured into Rome, without becoming a burthen to the respective inhabitants, and this principally from the means which their predecessors provided.

224. The aqueduct of Quintus Martius, erected 312 years before Christ, is among the most extraordinary of the Roman aqueducts. Commencing at a spring thirty-three miles distant from Rome, it made a circuit of three miles, and then, after being conveyed through a vault or tunnel of 16 ft. in diameter, continued for thirty-eight miles along a series of arcades 70 ft. in height. It was formed with three distinct channels, one above the other, conveying the water from three different sources. In the upper one was the Aqua Julia, in the next the Aqua Tepula, and in the lowest the Aqua Martia. The Aqua Virginia was constructed by Agrippa, and in its course passed through a tunnel 800 paces in length. The Aqua Claudia, begun by Nero, and finished by Claudius, of which *fig.* 125. shows several arches, conveyed water to Rome from a distance of thirty-eight miles; thirty miles of this length was subterraneous, and seven miles on arcades, and it still affords a supply of water to the city. The Anio was conveyed to Rome by two different channels: the first was carried over a length of forty-three miles, and the latter of sixty-three, whereof six miles and a half formed a continued series of arches, many of them upwards of 100 ft. in height above the ground on which they stood. At the beginning of the reign of Nerva, there were nine great aqueducts at Rome. That emperor, under the superintendence of Julius Frontinus, constructed five others, and at a later period there were as many as twenty. According to Frontinus (de Aquæductibus) the nine earlier aqueducts supplied 14,018 quinaria daily, which are equal to 27,743,100 cubic ft.; and it has been computed that when all the aqueducts were in delivery, the surprising quantity of 50,000,000 of cubic ft. of water was afforded to the inhabitants of Rome, so that, reckoning the population at one million, which it probably never exceeded, 50 cubic ft. of water were allowed for the consumption of each inhabitant. More magnificent Roman aqueducts are, however, to be found in the provinces than those that supplied the city. That of Metz, whereof many of the arcades remain, is one of the most remarkable; extending across the Moselle, a river of considerable breadth where it crosses it, it conveyed the water of the Gorse to the city of Metz. From the reservoir in which the water was received, it was conducted through subterranean channels of hewn stone, so spacious that in them a man might stand upright. The arches appear to have been about fifty in number, and about 50 ft. in height. Those in the middle of the river have been swept away by the ice, those at the extremities remaining entire. In a still more perfect state than that at Metz is the aqueduct of Segovia.

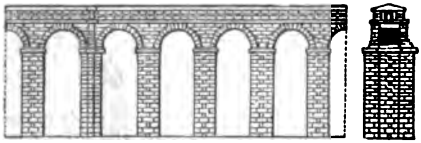


Fig. 125. AQUA CLAUDIA.

of which one hundred and fifty of the arches remain, all formed of large blocks unconnected by cement, in two ranks of arcades one above the other.

225. It has been conjectured that the causes for not carrying these aqueducts in straight lines were first to avoid excessive height, where low grounds were crossed, and, secondly, to diminish the velocity of the water, so that it might not be delivered to the city in a turbid state. Along the line of an aqueduct, according to Montfauçon, at certain intervals, reservoirs called *Castella* were formed, in which the water might deposit its silt; these were round towers of masonry raised of course as high as the aqueduct itself, and sometimes highly ornamented. The same author observes that below the general bed of the channel, pits were sunk for the reception and deposit of the earthy particles which the water contained. Vitruvius directs the channels to be covered over to protect the water from the sun's rays, and (lib. viii. chap. 7.) he moreover directs that when water-pipes are passed across a valley, a *venter* should be formed, which is a subterranean reservoir wherein the water may be collected, and by which its expansion may be diminished, so that the hydrostatical pressure will not burst the joints. He also recommends that open vertical pipes should be raised for the escape of the air which accompanies the water, a practice which the moderns have found it necessary to adopt wherever it is necessary to bend pipes upwards, and thus permit the escape of air, which would impede, and even stop altogether, the movement of the water in them.

226. *Theatres.*—The earliest stone theatre of Rome, as we have before stated (185.), was that of Pompey; but it must be recollected that as there are notices in history of this theatre having been more than once consumed by fire, there can be little doubt that a portion, probably the seats and scenes, were of wood. The second theatre of stone was raised by Julius Cæsar, after which Augustus reared one in honour of Marcellus, the son of his sister. The scanty ruins of this last enable one to do little more than trace its elevation, and from their curve to compute its extent. There was no *essential* difference between the form of the Roman and Greek Theatre, of which latter we have given a diagram in *fig.* 106. We nevertheless think it right here to present the reader with one of the Roman Theatre *fig.* 126.), as nearly as it can be made out from the description of Vitruvius. (Book v. Chap. 6. "The form of a theatre," according to that author, "is to be adjusted so, that from the centre of the dimension allotted to the base of the perimeter, a circle is to be described, in which are inscribed, at equal distances from each other, four equilateral triangles whose points must touch the circumference of the circle." — "Of these triangles the side of that which is nearest the scene determines the face of it, in that part where it cuts the circumference of the circle. A line drawn parallel to it through the centre will separate the *pulpitum* of the *proscenium* from the *orchestra*. Thus the pulpitum becomes more spacious and convenient that that of the Greeks, because our actors remain chiefly on the *scena*. In the orchestra are assigned seats to the senators: the height of its pulpitum must not exceed 5 ft., so that the spectators in the orchestra may have a clear view of the motions of the actors. The portions between the staircases (*cunei*) of the theatre are to be so divided that the vertices of the triangles, that touch the circumference, may point to the directions of the ascents and steps between the cunei on the first *præcinction* or story. Above these the steps are placed alternately and form the upper cunei in the middle of those below. The angles thus pointing to staircases will be seven in number, and the remaining five will indicate certain points on the scene. That in the centre, for instance, is the situation for the royal door, those on the right and left the doors of the guests, and those at the extremities the points at which the road diverges. The seats (*gradus*) for the spectators are not to be less than 20 in. in height nor more than 22. Their width is not to be more than 2½ ft. nor less than 2 ft." Besides the theatres named, that of Cornelius Balbus, built by him in honour of Augustus, was on a scale of considerable magnificence.

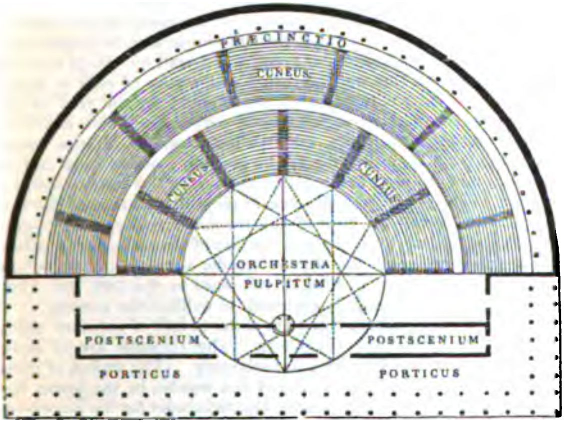


Fig. 126. PLAN OF THE ROMAN THEATRE.

227. The large theatre at Pompeii, as was frequently the case, was formed upon the slope of a hill, the corridor being the highest part, whence the audience descended to their seats, and staircases were saved. The *gradus* at this theatre were about 1 ft. 3 in. high, and 2 ft. 4 in. wide, and from a part which is divided and numbered off, 1 ft. 3½ in. appear to have been allotted to each spectator. There still remain some of the iron rings, for the reception of the masts from which the *velarium* or awning was suspended.

228. *Amphitheatres.* — The amphitheatre was unknown to the Greeks. At an early period, however, in Rome, human beings were compelled to fight for the amusement of spectators. The taste for such spectacles increased with its indulgence; but it was nevertheless not until the time of the emperors, that buildings were erected solely for exhibition of gladiatorial shows. The principal amphitheatres, of which remains still exist, are one at Alba, a small city of Latium; another near the Tiber at Otricoli; one of brick near the banks of the Garigliano; one at Puzzuoli, wherein parts of the arcades and caves for wild beasts still remain; one at Capua; another at Verona; a very fine one at Pola in Istria (*fig.* 127.). In France, Arles, Saintes Autun, Nismes, and Nice possessed amphitheatres. In short, wherever the Romans went, they erected those extraordinary monuments of their power and skill. But all that we have enumerated were far surpassed by the Coliseum, which has been already briefly mentioned by us at page 79. The form of this building on the plan is an ellipse, whose transverse exterior axis is 615 ft. and its conjugate 510 ft., covering therefore nearly six English acres of ground. The whole mass is placed on an ascent of six stages, which encircle its whole circumference. In the centre is the *arena*, a name which it received from being strewed with sand, the transverse and conjugate axes whereof are 281 and 176 ft. respectively. Round the arena was a wall on which was the *podium* or fence; and immediately behind this wall all round was a row of cells in which the beasts were placed preparatory to their entrance into the arena. In the rear of the cells was a corridor from which vaults radiated in directions perpendicular or nearly so to the curve of the ellipse, and serving to support the first *mœnianum* or interior range of seats. In some of these vaults were steps leading to the podium; others were merely passages between the first corridor and the next towards the interior. The second corridor was lighted by apertures cut through its vault to the *præcinctio* which separated the first and second horizontal division of the seats. In rear of the second corridor, vaults again radiated, in some whereof were steps leading to the second division of the seats, and in others were galleries which led from the corridor to the double arcade, surrounding the whole edifice. The description will be better comprehended by reference to *figs.* 128. and 129., in the latter whereof a portion of the exterior side is removed, to exhibit the section.

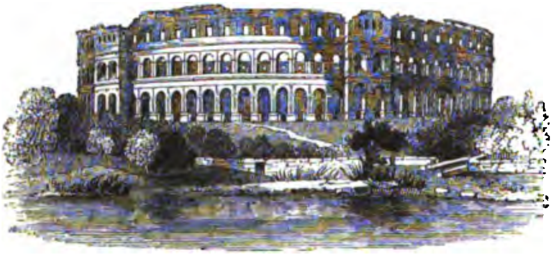


Fig. 127. AMPHITHEATRE AT POLA.

229. About the whole exterior of the building, there are three orders of columns rising above each other, and one of pilasters crowning the whole. The columns are of equal diameter, and are filled in between with eighty arcades in each story. The arches of these arcades have all archivolt mouldings round them. Four of the arcades in the lower tier were reserved for the admission of distinguished personages, the remainder for the populace; these last were called *vomitoria*, serving both for ingress and egress to and from the places of the spectators, by means of steps under the vaults that supported the seats. The piers which support the arches are 7 ft. 4. in. wide; on each is a half column projecting from the general face of the wall. The opening between the piers is 17 ft. $3\frac{6}{10}$ in. Impost mouldings are placed at the springing of the arches, and encircle the building except where interrupted by the columns and openings. The lower order resembles the Doric, except that the frieze is without triglyphs and the cornice without mutules. Desgodetz makes the height of the columns 27·63 ft., and their lower diameter 2·91 ft. Their diminution is very small. The height of the entablature is 6·64 ft., and the height, therefore, of the whole order above the pavement is 34·27 ft. The second order is Ionic, and stands on a dado 6 ft. high, broken under the columns to receive their projection from the wall. The columns are 25·73 ft. high. The volutes of the capitals are without ornament; the eye being merely marked by a circle. The entablature is 6·64 ft. high, and its subdivisions are like that in the order below. There are neither modillions nor dentils in the cornice. The height of the whole order is 38·37 ft. The third order is Corinthian, standing on a dado 6·39 ft. high. The columns are 25·58 ft. high, the entablature 6·59 ft., and the height of the entire order, including the dado, is 38·57 ft.

The upper story is decorated with a series of Corinthian pilasters on subplinths 2·79 ft. high, placed on a dado of the height of 7 ft. The height of the pilasters, which are not diminished, is 28 ft., and the height of their entablature is 7·37 ft. The frieze and architrave are broken vertically in each interpilaster over three corbels, on which it is supposed, running through the back part of the cornice, poles were placed for holding the *velarium*, which was occasionally stretched over the building to protect the spectators from the sun or rain. The whole height of the façade above the steps was 162 ft. The columns project rather more from the walls than their semidiameter; and the faces of the walls are not in the same vertical plane, but recede from it towards the interior of the building. The widths of the piers vary in the different stories, being respectively from the lower part upwards as 8·71, 8·38, and 7·28 ft. Between the pilasters, in the fourth order, are square windows. The velarium was attached to the poles round the circumference with a fall towards the interior, so that the rain was delivered into the arena. The following has been supposed as a method of spreading the velarium, of which Fontana gives a representation, but no description. A cable being placed round the edge, and following the curve of the podium, strong ropes were attached to it in the direction of the radiating walls on the plan, and passing through pullies in the poles at the top of the building, which were 240 in number, resting on the corbels before mentioned, so that the whole might be raised to the required height. It would follow the inclination of the seats, and the cloth, of whatever fabric or materials it might be, being formed in gores equal on the outer edges to the distance of the masts from each other, might move on the radiating ropes by rings attached to the edges of

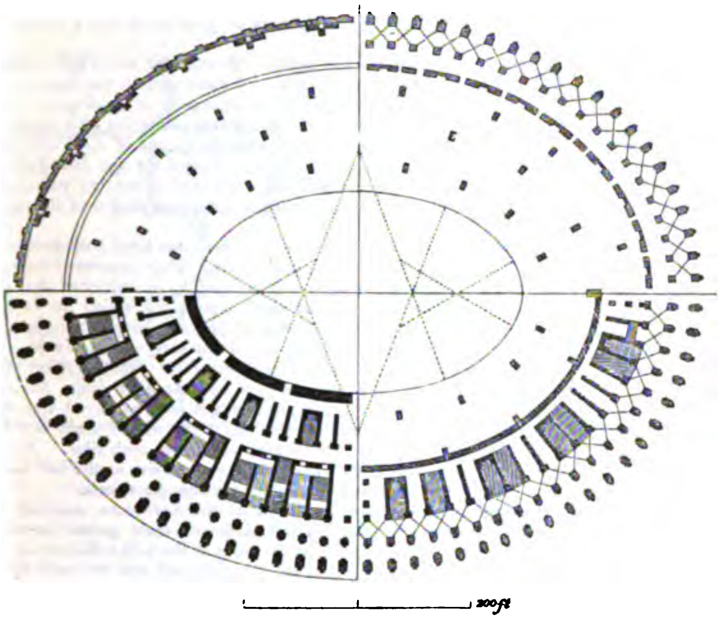


Fig. 128. PLAN OF COLISEUM.

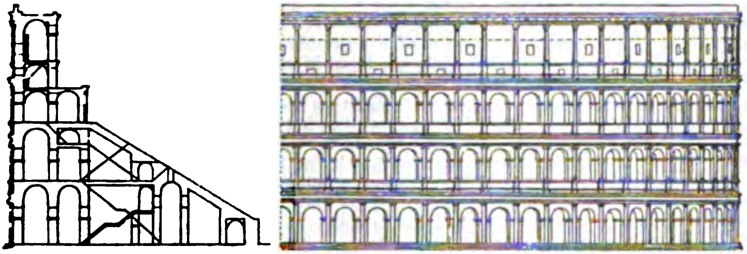


Fig. 129. SECTION AND ELEVATION OF COLISEUM.

each gore, so as to be moved backwards and forwards by persons stationed on the parapet. Marine soldiers were employed for this purpose. The velarium was sometimes of silk, but more usually yellow or brown woollen cloth. Nero once had a purple velarium stretched across the building, representing the heavens with stars of gold on it, and a design embroidered thereon of the Chariot of the Sun.

230. It has been conjectured by some Roman antiquaries that the arena was boarded; and, from the changes that could be made on it in a very short period, the conjecture is highly probable. Domitian covered it with water for the purpose of exhibiting marine shows and naval fights. Sometimes it was changed into the representation of a forest with wild beasts roaming about. These alterations were effected by means of machines called *pegmata*. In particular parts of the building, pipes were provided for the distribution of perfumes, which it was a common practice to sprinkle in showers; but, on particularly great occasions, the perfumes were allowed to flow down the steps or gradus of the amphitheatre.

231. The conjecture relative to the boarded floor of the arena has been corroborated by the discoveries made while the French had possession of Rome. They excavated the arena, and found vaults and passages under its whole area. It is much to be regretted that these inquiries were not carried on, owing to an accumulation of waters, for which no drainage having been provided, they became unwholesome from stagnancy, and it therefore was necessary once more to close it again by obvious means. Great care was bestowed on the drainage of this edifice, which was encircled by a large sewer for the reception of the water of the interior drains, that were all conducted into it. Another drain, 30 inches wide, was carried round under the second corridor, into which are conveyed the water from the perpendicular conduits and that from the third corridor, whose drain is 3 ft. in depth and 17 inches in width. The sides of these drains are lined with tiles. Another drain runs on the outer side of the third corridor, and is of the same size as the last named. Other drains communicate with these towards the arena in various directions.

232. Paoli thinks that amphitheatres were first used by the Etruscans, and by them introduced into Rome; that the people in question first exhibited their games in narrow valleys, and that the spectators were ranged around on the sides of the hills; that when these sports were exhibited in cities, an arena was dug into the level ground, and the earth thrown out was formed into seats; and that when the community became rich enough, or the games came to be held in greater esteem, the amphitheatre was enclosed with a wall, and the seats formed of wood or stone. It certainly appears to us that Paoli's conjecture is reasonable, and that Etruscan buildings or formations were the original type.

233. The amphitheatre at Nismes was capable of containing 17,000 persons: it was 400 ft. long and 320 ft. broad. That at Verona, upon whose age antiquaries are divided in opinion, some maintaining that it was built in the time of Augustus, and others as late as the time of Maximian, Maffei making somewhat of a mean between the two periods, is of an elliptical form, 508 ft. long and 403 ft. broad. It is in much better preservation than the Coliseum. Its exterior wall has three stories of Tuscan pilasters on the face of the wall, the two upper whereof stand on podia. Between these pilasters are arcades of semicircular-headed apertures. Maffei says, that allowing a foot and a half of room for each person, this edifice would seat 22,000 spectators.

234. *Baths.* — Publius Victor says that the city of Rome contained public and private baths to the amazing number of 850. Some of these we know, from their ruins, were buildings of great extent and magnificence. They were all constructed, we mean the public ones, on plans very similar; and, in order to a description of them, we give in *fig.* 130. a restored plan of the baths of Caracalla, at Rome. Those of Titus and Dioclesian may also be traced; the chief others being those of Agrippa, Nero, and Domitian. The baths of Antoninus Caracalla are thus described by Eustace (vol. i. p. 226.): "Repassing the Aventine Hill, we came to the baths of Antoninus Caracalla, that occupy part of its declivity, and a considerable portion of the plain between it, Mons Cæliolus and Mons Cælius. No monument of ancient architecture is calculated to inspire such an exalted idea of Roman magnificence as the ruins of their thermæ, or baths. Many remain in a greater or less degree of preservation; such as those of Titus, Dioclesian, and Caracalla. To give the untravelled reader some notion of these prodigious piles, I will confine my observations to the latter, as the greatest in extent and as the best preserved; for, though it be entirely stripped of its pillars, statues, and ornaments, both internal and external, yet its walls still stand, and its constituent parts and principal apartments are evidently distinguishable. The length of the thermæ was 1840 ft., its breadth 1476. At each end were two temples; one to Apollo, and another to Esculapius, as the tutelary deities (*genii tutelares*) of a place sacred to the improvement of the mind and the care of the body. The two other temples were dedicated to the two protecting divinities of the Antonine family, Hercules and Bacchus. In the principal building were, in the first place, a grand circular vestibule, with four halls on each side, for cold, tepid, warm, and steam baths: in the centre was an immense square for exercise, when the weather was unfavourable to it in the

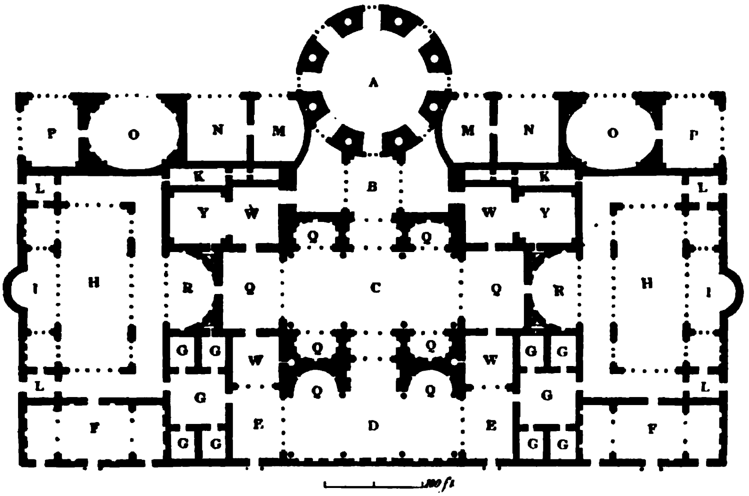


Fig. 130. BATHS OF CARACALLA.

open air; beyond it a great hall, where 1600 marble seats were placed for the convenience of the bathers: at each end of this hall were libraries. This building terminated on both sides in a court surrounded with porticoes, with a spacious odeum for music, and in the middle a spacious basin for swimming. Round this edifice were walks shaded by rows of trees, particularly the plane; and in its front extended a gymnasium for running, wrestling, &c. in fine weather. The whole was bounded by a vast portico, opening into exedræ, or spacious halls, where the poets declaimed and philosophers gave lectures to their auditors. This immense fabric was adorned within and without with pillars, stucco work, paintings, and statues. The stucco and paintings, though faintly indeed, are yet in many places perceptible. Pillars have been dug up, and some still remain amidst the ruins; while the Farnesian bull and the famous Hercules, found in one of these halls, announce the multiplicity and beauty of the statues which adorned the thermæ of Caracalla. The flues and reservoirs of water still remain. The height of the pile was proportioned to its extent, and still appears very considerable, even though the ground be raised at least 12 ft. above its ancient level. It is now changed into gardens and vineyards; its high massive walls form separations, and its limy ruins, spread over the surface, burn the soil and check its natural fertility."

235. Returning to the plan of the baths in question, we have now to explain that the circular apartment, lettered A, was called the solar cell. It was 111 ft. in diameter, and contained the different *labra* of the baths. This solar cell, Spartianus says, could not be equalled by the best architects of that age. The dome was lined with brass, of which material also were the lattices to the windows. B, the *apodyterium*, or undressing room. C, a *xystus*, or apartment for exercise in unfavourable weather. D contained the piscina, or large reservoir for swimming. E, vestibule for spectators and the dresses of the bathers. F, entrance vestibule of the thermæ, having libraries on each side. G G, rooms wherein the athletæ prepared for their exercises. H, a court, having a piscina for bathing in the centre. I, *ephebeum*, place of exercise for the youth. K K, the *elæotherium*, or apartment for anointing the bathers with oil. L L, vestibules. M, *laconicum*, an apartment so called, as it is said, from the name of the stove by which it was heated, and from the custom of the *sudatio*, or sweating, having originated in Laconia. N, *caldarium*, or hot water bath, which was most frequented. O, *tepidarium*, or tepid water bath. P, *frigidarium*, or cold water bath. Q, *exedræ* for seats for the use of the philosophers and their scholars. W, rooms for conversation. R R, *exedræ*, or large recesses for the use of the philosophers. Y, *conisterium*, or place where, after anointing, the wrestlers were sprinkled with dust.

236. We have just given the common explanation to the word laconicum; but it is right the reader should know that its true meaning is in some doubt. Galiani considers it a great chamber wherein the people underwent sweating. To this Cameron adds, "I for myself hold it certain that the apartment for this purpose has been by some authors improperly termed; the laconicum is nothing more than a little cupola which covered an aperture in the pavement of the hot bath, through which the vivid flame of the hypocaustum, or furnace, passed and heated the apartment at pleasure. Without this means," continues that author, "the hot bath would not have had a greater heat than the other chambers, the

temperature of which was milder. I have been induced to form this opinion, not only from the ancient paintings found in the baths of Titus, but also by the authority of Vitruvius, who says that the hot bath (*concamerata sudatio*) had within it, in one of the corners, or rather ends, the laconicum. Now, if the laconicum was in the corner of the hot bath, it is clear that it is not the bath itself, but merely a part of it; and if, as others have thought, it was the hot bath itself, to what purpose served the concamerata sudatio?"

237. The baths and thermæ of the Romans, like the gymnasia of the Greeks, were highly ornamented with bassi relievi, statues, and paintings. The basins were of marble, and the beautiful mosaic pavements were only equalled by the decorations of the vaults and cupolas. Nothing more strongly proves the magnificence and luxury of the ancient Romans than the ruins of the baths still to be seen in Rome. Agrippa decorated his baths with encaustic paintings, and covered the walls of the caldarium with slabs of marble, in which small paintings were inserted. All these luxuries were introduced under the emperors; and the mere act of bathing, as described by Seneca in the instance of Scipio Africanus, appears to have been almost lost in the effeminacy of the later practice. The splendour of the places may be judged of by calling to the remembrance of the reader that the celebrated statue of the Laocoon was one of the decorations of the baths of Titus, and that of the Farnese Hercules of the baths of Caracalla.

238. We have, in the section on Aqueducts (224.), stated the extraordinary quantity of water with which the city was supplied by them, and there can be no doubt that the baths caused a very great consumption of that necessary article of life. After the removal of the empire to Constantinople, we hear of no thermæ being erected; and it is probable that at that period many of those in the city fell into decay. The aqueducts by which they were supplied were, moreover, injured by the incursions of invaders, another cause of the destruction of the baths. Remains of Roman baths have been discovered in this country, for descriptions whereof the reader is referred to the *Archæologia*.

239. We shall conclude our observations on the Roman baths by the mention of some curious paintings in the baths of Titus, very similar in their features to those found in places on the walls of Pompeii; we allude to representations of slender twisted columns, broken entablatures, and curvilinear pediments, columns standing on corbels attached to the walls, a profusion of sculpture, with fantastic animal figures and foliage, and many other *estravaganzas*, which found imitators after the restoration of the arts, and, in some cases, with great success.

240. *Circi.* — The circus of the Greeks was nothing more than a plain, or race course; from its length called Στάδιον (stadium); as also Κιρκος, from its oval figure. With the Romans it became a regular building of great dimensions and magnificence. The *Circus Maximus*, constructed originally in a rude manner by Romulus, and afterwards rebuilt by the elder Tarquin, is, in its external dimensions, computed to have been 2000 ft. long and 550 ft. broad, consisting of two parallel walls in the direction of its length, united at one extremity by a set of apartments, called *carceres*, arranged in the form of the segment of a circle of about 430 ft. radius; and, at the opposite short end, by a semicircular enclosure. The carceres contained the chariots ready for starting. The *arena*, or space thus enclosed, contained a long low wall called the *spina*, 1300 ft. in length, running along its longitudinal axis, and commencing at the centre of the semicircular end, having a *meta*, or goal, at each of its extremities. Like those of the theatre and amphitheatre, the seats of the spectators were placed round the arena with a podium in front; between which and the spina the races of the chariots were exhibited. The circus of Nero was nearly of the same form, but neither so long nor so broad, being only 1400 ft. in length and 260 in breadth, and its spina but 800 ft.

241. The remains of the circus of Caracalla, of which Bianconi has given a very good account, are still sufficiently abundant to trace the plan (*fig.* 131.). It was nearly of the same dimensions as that of Nero. There are in this building come curious examples of lightening the spandrels of the arches over which the seats were constructed, by filling them in with light vessels of pottery; a practice which has been partially adopted in some modern buildings, and is still usefully practised on the Continent. Generally speaking, the circus was a parallelogram, whose external length was from four to five times its breadth. It was surrounded by seats ranged above each other and bounded by an exterior wall, probably pierced with arcades. The spina was about two thirds the length of the building, and was ornamented with statues, obelisks, and other ornaments, terminated at each end by the meta, which consisted of three obelisks or columns. The carceres were closed by gates in front and rear, which were not opened till the signal was given for starting. In the circus of Caracalla, it will be seen that these carceres were placed obliquely to the long sides of the edifice, so as to equalise the length of their course from the starting point to the goal. So that it would seem there was as much nicety in a chariot race of old as in a modern horse race.

242. *Private Houses.*—The domestic architecture of the Romans possesses great interest; the general instructions spread over the sixth book of Vitruvius upon their parts and pro-

portions have received much illustration from the discoveries at Pompeii; and it is pleasant to find that, following his merely verbal directions, a building might be planned which would correspond as nearly with what we now know was the case, as two houses, even in a modern city, may be expected to resemble one another. In the following observations we have used most abundantly the elegant little work of Mazois (*Le Palais de Scaurus*, 2d ed. 8vo. Paris, 1822), and feel a pleasure in thus acknowledging our obligations to that author; but, before more immediately using his observations on the later habitations of the Romans, we shall premise that until after the war of Pyrrhus, towards the year 280 B.C., the use of tiles as a covering for them appears to have been unknown. Till then thatch or shingles formed the covering of the houses. They consisted of a single story; for, according to Pliny (lib. xxxiv. c. 15.) and Vitruvius (lib. ii. c. 8.), a law was in force forbidding walls of a greater thickness than one foot and a half; whence it is clear they could not have been safely raised higher than a single story with the unbaked bricks then in use. But the space within which the city was confined, with an increasing population, rendered it necessary to provide in height that which could not be obtained in area; so that, in the time of Augustus, the height of a house was limited to 70 ft. (*Aurel. Vict.*; and *Strabo*, lib. v.)

243. The extraordinary fortunes that were realised in Rome towards the last years of the republic, when the refinements of the arts of Greece were introduced into the city, soon led its more favoured citizens to indulge in architectural splendour. Lucius Cassius had decorated his dwelling with columns of foreign marble; but all other private edifices were thrown into shade by that of Scaurus, in which were employed black marble columns of the height of 38 ft. Mamurra lined his apartments with marble; and, indeed, such was the prodigality, for it deserves that term, of the Romans, that Pliny (lib. xvii. c. 50.) tells us of Domitius Ahenobarbus having offered a sum equivalent to 48,500*l.* sterling (sexagies sestertium) for the house of Crassus, which was refused. Their villas were equally magnificent. Cicero had two — his Formian and Tusculan villas; but these were exceeded in beauty by those of Lucullus and Pollio, the latter near Posilippo, where some remains of it are still to be seen. Though Augustus attempted to stop this extraordinary rage for magnificence, he was unsuccessful; and the examples which were afforded by later emperors were unlikely to restrain the practice where the means existed. In the Domus Aurea of Nero, domestic architecture appears, from all accounts, to have reached the utmost degree of splendour and magnificence.

244. In the better class of Roman dwellings, certain apartments were considered indispensable; and these, in different degrees of size and decoration, were always found. There were others which were or were not so found, according to the wealth and fancy of the proprietor. Thus, every private house of any pretension was so planned that one portion was assigned to the reception of strangers, or rather for public resort, and the other for the private use of the family. The public part was destined for the reception of dependants or *clients*, who resorted to the house of their patron for advice and assistance.

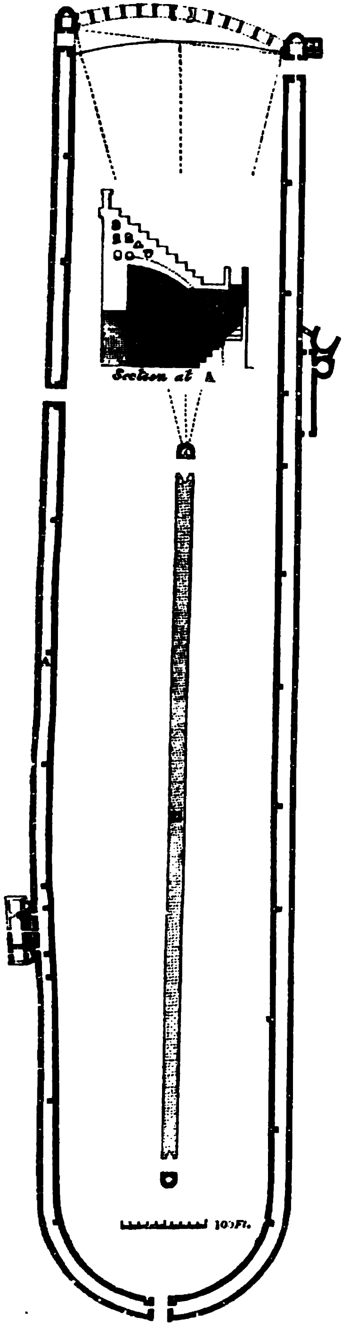


Fig. 138. PLAN OF CIRCUS OF CARACALLA.

The number of these clients was honourable and useful to the patron, as they might, in civil matters, be depended on for their votes. Hence lawyers especially had their houses thronged with them; and it is amusing in the present day to see the term of *client* still kept up among our barristers: for although his state of dependence has lost nothing of its extent, the eminence of the patron is now measured by the quantity and amount of fees his clients enable him to consume. Vitruvius describes the public portion as consisting of the *porticus*, *vestibulum*, *cavædium* or *atrium*, *tablinum*, *alæ*, *fauces*, and some few others, which were not added except at the especial desire of the party for whom the building was to be erected.

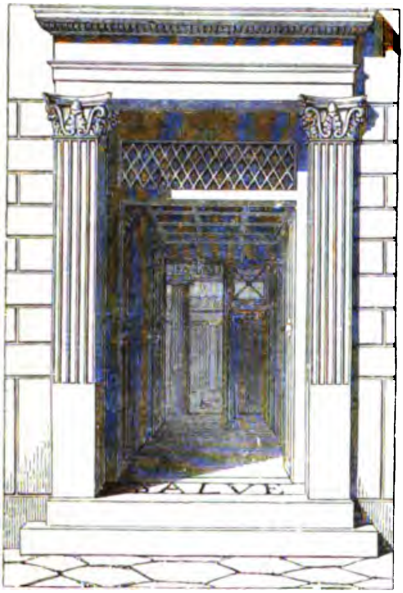


Fig. 132. DOOR AND PROTHYRUM, POMPEII.

245. The parts which were sacred to the use of the family were the *peristyle*, the *cubicula* (sleeping apartments), the *triclinium*, the *œci*, the *pinacothecæ*, or picture galleries, the *bibliotheca*, or library, baths, *exedræ*, *xysti*, and others.

246. In the more extended mansions of the Romans was an area, surrounded on two sides by porticoes and shops, and ornamented with statues, trophies, and the like, and on the third (the fourth being open) was the decorated entrance or portico of the house. But in smaller dwellings this entrance or portico was in a line with the front of the houses in the street; the vestibule or *prothyrum* (*fig.* 132.) being in the Roman houses merely a passage room, which led from the street to the entrance of the atrium. In this vestibule, or rather by its side, the *ostiarius* or porter was stationed, as in French houses we find a *concierge*. When there were two courts, we are inclined to think that the one nearest the street was called the *atrium*, and the farthest from it the *cavædium*; but in many cases we also think that the atrium served equally as a cavædium according to the owner's rank. The explanation of Varro will certainly answer for one as well as the other. It may be that the cavædium was a second atrium of larger size.

247. Of the atrium Vitruvius describes five sorts: 1. The *Tuscan*, wherein the protecting roof was a sort of pent-house on the four sides, supported by beams framed at right angles into each other; the space in the centre forming the *compluvium*, and the basin or area in the centre the *impluvium*. 2. The *tetrastyle* atrium (one with four

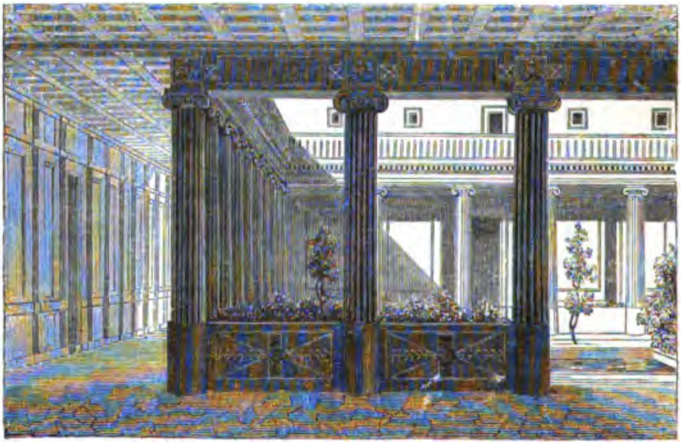


Fig. 133. CORINTHIAN ATRIUM.

columns), which was similar to the Tuscan, except that the angles of the beams of the roof or pent-house rested on four columns. 3. The Corinthian atrium (*fig.* 133.), which differed only from the last in its size, and the number of its columns. 4. The *atrium displuviatum* in which the slope of the roofs was towards the body of the building. 5. The *atrium testudinatum*, which was covered with a ceiling, and with nothing more than an aperture therein to afford light. The compluvium was sometimes (*Plin.* xix. c. i.) provided with a sort of awning. The roof of the four sides of the atrium was covered with ornamental tiles, the eaves' faces whereof were terminated between their sloping junctions with carved faces called *antefixæ*, similar to those in the roofs of the Grecian temples. The atrium was, moreover, frequently embellished with fountains. It was in the atrium that the splendid columns which we have mentioned, as decorating the house of Scaurus, were placed. The walls were either lined with marble or painted with various devices, and the pavement was decorated with mosaic work or with precious marbles.

248. The *tablinum*, which usually opened towards the atrium, seems to have been a sort of levee room, wherein the master of the mansion received his visitors or clients, lists of whom were therein recorded, and where the *maestro di camera* announced their names. Some have thought, and we do not say they are wrong, that this apartment contained (which it might also do without affecting the truth of the first supposition) the family archives, statues, pictures, pedigree, and other appurtenances incident to a long line of ancestors.

249. The apartments on the sides right and left of the tablinum were called, as their name signifies, *alæ*. These were also furnished with portraits, statues, and other pieces relative to the family, not omitting inscriptions commemorative of actions worthy their name.

250. Two corridors, one on each side of the atrium, which led to the interior of the house from the atrium, were called *fauces* (jaws).

251. In houses of moderate dimensions, chambers were distributed round the atrium for the reception and lodging of strangers; but in establishments of importance, wherein the proprietor was a person of extended connexions, there was a separate *hospitium* appropriated to that purpose.

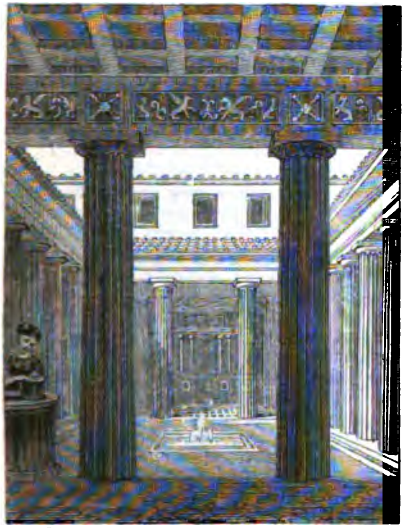


Fig. 134. PERISTYLE AT POMPEII.

252. We have stated that the peristyle was a portion of the private part of the house. It was mostly, if not always, placed beyond the atrium, with which it communicated by means of the tablinum and fauces. Similar in general form and design to the atrium, for it was surrounded by columns (see *fig.* 134.), it was larger than that apartment. The centre was usually provided with a parterre in which shrubs and flowers were distributed, and in its middle a fish pool. This portion of the peristyle was called the xystus (*Vitr.* lib. vi. c. 10.). In better houses there was an ante-room called *procœton*, to each of the bed-chambers, of whose arrangement very little is known. The triclinium (τρεις κλιναι, three beds), or dining-room, was so called from its having three couches round the table on which the dinner was served; the fourth side being left open for the servants (see *fig.* 135.). It was raised two steps from the peristyle, and separated from the garden by a large window. Winter triclinia were placed towards the west, and those for summer to the east. In large houses there were several triclinia, whose couches would contain a greater or less number of people. The *œci* were large *salons* or halls, of Greek origin, and, like the atria, were of more than one species; as for instance the tetrastyle, the Corinthian, and the Egyptian. "There is this difference," observes Vitruvius (lib. v. cap. 6.), "between the Corinthian and Egyptian œcus. The former has a single order of columns, standing either on a podium or on the ground, and over it architraves and cornices, either of wood or plaster, and a semicircular ceiling above the cornice. In the Egyptian œcus, over the lower column, is an architrave, from which to the surrounding walls is a boarded and paved floor, so as to form a passage round it in the open air. Then, perpendicularly over the architrave of the lower columns, columns one fourth smaller are placed. Above their architraves and cornices, they are decorated with ceilings, and windows are placed between the upper columns. Thus they have the appearance of basilicæ rather than of Corinthian triclinia." The œcus, called Cyzicene by the Greeks, was different to those of Italy. Its aspect was to the north, towards the gar-

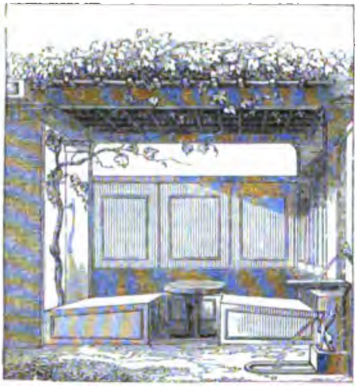


Fig. 135. SMALL TRICLINIUM AT POMPEII.

dens, and had doors in the middle. It was made long, and broad enough to hold two triclinia opposite to each other. The Greek œcus was not, however, much used in Italy. The *pinacotheca* (picture room), where possible, faced the north: both this and the *bibliotheca* (library), whose aspect was east, do not require explanation. The *exedræ* of the Roman houses were large apartments for the general purposes of society. The upper stories of the house, the chief being on the ground floor, were occupied by slaves, freedmen, and the lower branches of the family. Sometimes there was a *solarium* (terrace), which was, in fine weather, much resorted to.

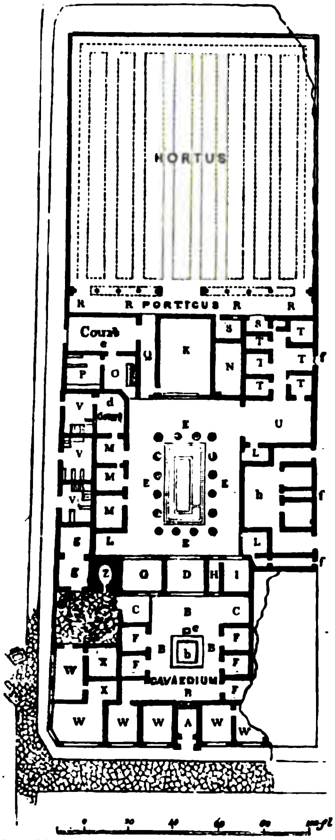


Fig. 136. PLAN OF HOUSE OF PANSA.

253. *Fig.* 136. is a plan of the house of Pansa at Pompeii, by reference to which the reader will gain a tolerable notion of the situation of the different apartments whereof we have been speaking. A is the prothyrum, which was paved with mosaic. B B B B, Tuscan atrium, in whose centre is the compluvium or basin (b) for the reception of the water from the roof. One of the proportions assigned to the atrium by Vitruvius is, that the length shall be once and a half the breadth; and here it is precisely such. c, a pedestal or altar of the household god. C C, alæ. They were on three sides surrounded by seats, and, from Sir W. Gell's account, are analogous to similar recesses in the galleries of Turkish houses, with their divans: the thresholds were mosaic. Vitruvius directs them to be two sevenths of the length of the atrium; which is precisely their size here. D, tablinum. It was separated from the atrium by an aulæum, or curtain, like a drop scene. Next the inner court was sometimes, perhaps generally, a window, occupying the whole side. The tablinum was used as a dining-room in summer. E E E E, peristyle, which, in this example, exactly corresponds with the proportions directed by Vitruvius. F F F F were domestic apartments, as penaria, or cubicula, or cellæ domesticæ. G, probably the pinacotheca, or apartment for pictures. H, fauces, or passage of communication between the outer and inner divisions of the house. I, cubiculum. Its use cannot be doubted, as it contains a bedstead, filling up the whole width of the further end of it. K, triclinium, raised two steps from the peristyle, and separated from the garden by a large window. In this room company was received, and chairs placed for their accommodation. L L L, exedræ. M M M, cellæ familiariæ, or family chambers: the further one had a window looking into a court at d. N, lararium or armarium, a receptacle for the more revered and favourite gods. O, kitchen with stoves therein, and opening into a court at e, and an inner room P, in which were dwarf walls to deposit oil jars. Q, fauces conducting to the garden. Along the back front, R R R R, is a portico or pergula, for training vines and creepers on the back front of the house, before the windows of the triclinium. S S: these two rooms, opening into the pergula, were, it is presumed, cubicula. T T, &c.: the apartments thus marked seem to have constituted a distinct portion of the house, and communicated with the street by a separate door. That they were in-

cluded in the establishment of Pansa seems certain, from their being connected with the peristyle by the large apartment U. On excavating here, four skeletons of females were found marked by their gold ear-rings; also a candelabrum, two vases, a fine marble head of a faun, gold bracelets, rings with engraved stones, &c. &c. V V V are shops, which appear, by the remains of staircases, to have had apartments above. They contain dwarf walls for ranging oil jars and other goods against. W W, &c. are different shops. One is of a baker, and to it the necessary conveniences are appended. X X, apotheca or store-rooms. Y is the bakehouse, containing the oven Z, the mills, a kneading trough, &c. : it is paved with volcanic stone in irregular polygons. g g, place for the wood and charcoal. h appears to have been almost a distinct dwelling: two of the apartments had windows to the street, which runs southward to the forum. f f f, entrances from the street to the house of Pansa. The house was surrounded by streets, or, in other words, was an insula. We have thus named the principal apartments, and identified them by an example. In more magnificent houses there were the sacrarium, the venereum, the sphæristerium, the aleatorium, &c. &c. The painting *fig.* 137. is in the kitchen of the house at Pansa, and represents the worship of the lares, under whose care and protection the provisions and cooking utensils were placed.

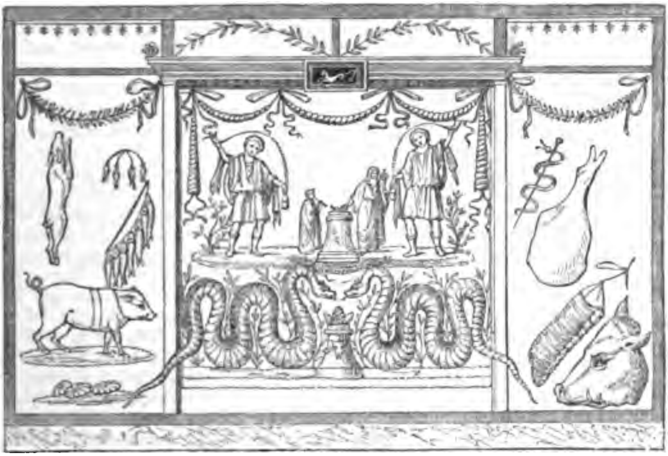


Fig. 137. PAINTING AT POMPEII.

254. *Tombs.*—The Romans were rather given to magnificence in the tombs erected for their dead. Some of these were public, and others for the interment of individuals or families. The former were often of vast extent, and have been compared to subterranean cities; the others were pyramids, conical and cylindrical towers, with ranges of vaults in them for sepulture.

255. Perhaps the earliest tomb at Rome is that of the Horatii, which stands on the Appian Way, and was probably constructed by Etruscan workmen. It has a basement 45 ft. square on the plan, on which stand five masses of rubble or earth, faced with masonry, in the form of frusta of cones, four of which are ten feet diameter at the bottom, and are placed at the four angles of the basement. The fifth stands in the centre of the whole mass, and is larger than the others.

256. The principal tombs about Rome are, 1. The pyramid of Caius Cestius, whose sides are 102 ft. long, and its height about the same number of feet. The interior contains in the centre a rectangular cell, 20 ft. long, and 13 ft. broad. At each external angle of this pyramid stands a Doric column, without any portion of entablature over it. It is possible these were intended as ornaments, though it has often puzzled us to find out how they ever could have been so thought. 2. The tomb of Adrian, now converted into the Castel St. Angelo, had originally a square basement, whose sides were 170 ft. long. From this substructure rose a cylindrical tower, 115 ft. diameter, probably at one time encircled by a colonnade. It is now used as a fortress, and was considerably altered by Pope Paul III. 3. The mausoleum of Cecilia Metella is a circular building, 90 ft. in diameter, and 62 ft. high, standing on a basement of the same form. Up to the frieze the tomb is of Travertine stone, but the frieze itself is of marble, with sculptured rams' heads and garlands. In what may be called the core is a cell, 19 ft. diameter, to which there is an entrance by a passage on the exterior.

257. We do not, however, think it necessary further to detail the Roman tombs which may be found in Rome or the provinces, but, in lieu of extending our description on this

head, to give the reader a notion of their forms in *fig.* 138. by a group from Pompeii, among the remains of which city there are a great many and various examples. They are in general of small dimensions, and stand so near one another as to form a street, called the Street of the Tombs. Some of these are decorated very highly, both as respects ornament in the architecture and bassi relievi on the different faces. The Romans were particular in keeping alive the memory of the dead, hence their tombs were constantly looked after and kept in repair; a matter which, in this country of commerce and politics, a man's descendants rarely think of, after dividing the spoil at his death.

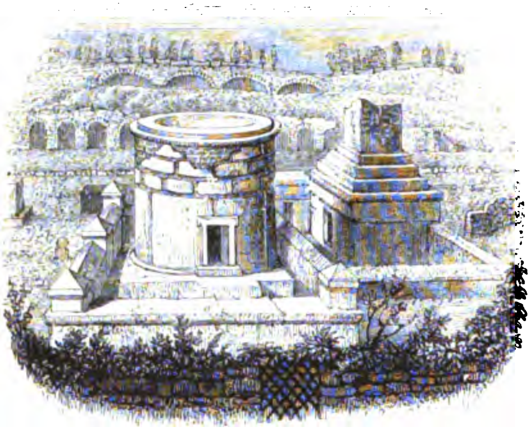


Fig. 138. TOMBS AT POMPEII.

258. *Character of Roman Architecture.*—The character of the Roman architecture in its best period was necessarily very different from the Grecian, on which it was founded. We envy not those who say that they feel no beauties except those which the pure Grecian Doric of the Parthenon possesses. Each style, in every division of architecture, has its beauties; and those, among other causes, arise from each style being suited to the country in which it was reared; neither can we too often repeat the answer which Quatremère de Quincy gives in the *Encyclopedie Méthodique* to the question many years since propounded by the French Academy of Inscriptions and Belles Lettres, "Whether the Greeks borrowed their architecture from the Egyptians?" The answer of that highly talented writer is, "That there is no such thing as general human architecture, because the wants of mankind must vary in different countries. The only one in which the different species of architecture can approach each other is intellectual; it is that of impressions, which the qualities whose effects are produced by the building art can work upon the mind of every man, of every country. Some of them result from every species of architecture,—an art which sprung, as well from the huts of Greece, as from the subterraneous excavations of Egypt, from the tents of Asia, and from several mixed principles to us unknown. Thus the use of the word architecture is improper. We ought to name the species; for between the idea of architecture as a genus and as a species there is the same difference as between language and tongue; and to seek for a simple origin of architecture is as absurd as a search would be after the primitive language. If so, the hut of Vitruvius would be but an ingenious fable, as some have said; but it would be a ridiculous falsehood if he had pretended that it was the type of *all* architecture." If we must confine ourselves to the simplicity and purity of line which the Greek temple exhibits,—circumstances, be it observed, that no future occasion can ever again effectually call up,—all the admiration of the numberless monuments of the Romans is based upon false data, and we are not among those who feel inclined to set ourselves up against the universal consent of our race. Thus far we think it necessary to observe on the silly rage which a few years ago existed for setting up in this metropolis pure Greek Doric porticoes and pure Greek profiles. What could more exhibit the poverty of an artist's imagination, for instance, if the thing exist, than appending to a theatre the Doric portico of a temple? But the thing is too ridiculous to dwell on, and we proceed to our purpose. Whether the Romans invented the Tuscan order we much doubt. No example of it exists similar in formation to that described by Vitruvius: it must, however, be admitted that it is a beautiful combination of parts, and worthy so great a people. It seems highly probable that this order was used by the Etruscans, and that to them its origin is attributable. The use of timber in the entablature, which we know was practised by them to a great extent, seems to sanction such an hypothesis. Its detail, as well as that of the other orders of architecture, belong to another part of this work; we shall not therefore further speak of it than in the language of Sir Henry Wotton, who says, with his usual quaintness and simplicity, that it is a sturdy labourer in homely apparel.

259. The Doric order with the Romans was evidently not a favourite. In their hands its character was much changed. The remains of it in the theatre of Marcellus, in the examples at Cora and Pompeii, and the fragment at the baths of Dioclesian, are not sufficient, the case of the first only excepted, to justify us in detaining the reader on the matter. The

lower order of the Coliseum, be it observed, wants the triglyph, the distinguishing feature of the order; so that although in a previous page we have described it as Doric, we scarcely know whether we have not erred in our description. But to approach the subject of the Roman Doric more closely, we will examine the general form of the example which the theatre of Marcellus affords. Therein the whole height of the order is 31·15 ft. whereof the entablature is rather more than one fifth, and the columns are 7·86 diameters high. From the intercolumniations nothing can be deduced, because the arcade which separates puts them out of comparison with other examples. Its profile is clearly that which has formed the basis upon which the Doric of the Italian architects is founded; they have, however, generally added a base to it. There is great difference between it and the Grecian Doric, which in its form is much more pyramidal, and would, even in ancient Rome, have been out of character with the decorations applied in the architecture of the city, in which all severity of form was abandoned. The details, however, of the Roman as well as of the Grecian Doric will be given, and, from the representations, better understood by the reader, when we come to treat of the Orders in the third book of this work, where some varieties of it are submitted to the reader.

260. In the examples of Roman Ionic, that of the theatre of Marcellus excepted, there is a much greater inferiority than in the instance of Roman Doric to which we have just alluded; indeed, that of the Temple of Concord is composed in so debased a style, that it ought scarcely to be alluded to. The following table exhibits the general proportions of the four Roman profiles of it: —

	Height divided by lower Diameter in English Feet.	Diameters in Height.	Entablature in Terms of the Diameter.	Intercolumniation.	Height of Capital in Terms of the Diameter.	Upper Diameter of Shaft.
Fortuna Virilis (Temple of) -	$\frac{27\cdot348}{3\cdot109} =$	8·796	2·182	2·125	·457	·874
Concord (Temple of) -	$\frac{42\cdot861}{4\cdot486} =$	9·554	1·605	1·807	·500	·325
Marcellus (Theatre of) -	$\frac{23\cdot940}{2\cdot660} =$	9·000	2·391	- -	·557	·842
Coliseum - - -	$\frac{25\cdot731}{2\cdot91} =$	8·842	2·280	- -	·466	·833

261. From the above it appears that, except in the case of the Temple of Concord, the entablature is about one fifth of the height of the whole order, and that the column diminishes about $\frac{18}{100}$ of its lower diameter. The capitals of the Roman are much smaller than those of the Grecian Ionic, and their curves are by no means so elegant and graceful. There is no appearance of refinement and care in their composition, than which the rules of Vitruvius give an altogether much more beautiful profile than those examples we have here quoted present. In the Temple of Concord, the volutes are placed diagonally on the capital, so that the four faces are similar in form. In the Greek specimens, as also in the Temple of Fortuna Virilis, this is done on one angle only of the capital of the columns, and that for the purpose of again bringing the faces of the volutes on to the flanks of the building, instead of showing the baluster sides of the capitals. On the whole, we think the modern Italian architects succeeded in producing much more beautiful profiles of this order, which never appears to have been a favourite in Rome, than their ancient predecessors.

262. The Corinthian seems to have been greatly preferred to the other orders by the luxurious Romans. There is little doubt that the capitals were generally the work of Greek sculptors, and some of those they have left are exceedingly beautiful; one that we have already mentioned, that of Jupiter Stator, points to sculpture of the highest class. The following table contains the general proportions of six well-known examples in Rome: —

	Height divided by lower Diameter in English Feet.	Diameters in Height.	Entablature in Terms of the Diameter.	Intercolumniation.	Height of Capital in Terms of the Diameter.	Upper Diameter of Shaft.
Pantheon, Portico - -	$\frac{47\cdot029}{4\cdot797} =$	9·804	2·317	2·092	1·175	·855
Pantheon, Interior - -	$\frac{34\cdot674}{3\cdot642} =$	9·499	2·251	1·834	1·000	·866
Jupiter Tonans - -	$\frac{47\cdot084}{4\cdot598} =$	10·241	2·069	1·558	1·167	·867
Jupiter Stator - - -	$\frac{47\cdot649}{4\cdot841} =$	9·820	2·534	1·575	1·08	·891
Façade of Nero - - -	$\frac{63\cdot5}{6\cdot368} =$	9·973	2·439	- -	1·269	·883
Arch of Constantine - -	$\frac{28\cdot037}{2\cdot902} =$	9·661	2·388	- -	1·095	·882

263. From the above, it appears that a mean of the whole height of the Corinthian order in the Roman examples is 12·166 diameters, and that the entablature is less than a fifth

of the height of the order, being as ·1686 : 1·0000. The diminution of the shaft is not so much as in the Ionic, being only $\frac{134}{1000}$ of the lower diameter. The Temple of the Sybil at Tivoli presents quite a distinct species, and is the romance of the art, if we may be allowed such an expression. The mean height of the columns is 9·833 diameters, being rather slenderer than the height recommended by Vitruvius (Lib. iv. c. 9.). The attic base, which will be considered in another portion of the work, was frequently employed by the Roman artists.

264. The invention of the Composite order is attributed, with every probability, to the Romans. It resembles generally the Corinthian, the main variation consisting in the part above the second tier of leaves in the capital. The following table exhibits the general proportions of three examples: —

Example.	Height divided by lower Diameter in English Feet.	Diameters in Height.	Entablature in Terms of the Diameter.	Height of Capital in Terms of the Diameter.	Diameter at top of Shaft.
Arch of Titus - - -	$\frac{22{\cdot}066}{2{\cdot}07}$ =	10·662	2·533	1·287	·887
Arch of Severus - -	$\frac{23{\cdot}847}{2{\cdot}887}$ =	8·260	2·316	1·144	·882
Baths of Dioclesian - -	$\frac{48{\cdot}476}{4{\cdot}619}$ =	10·495	2·3	1·181	·802

265. The mean of these makes the entablature a little less than one fifth of the entire height of the order, the ratio being as ·1955 : 1·0000. The diminution of the shaft is $\frac{143}{1000}$ of the lower diameters. The mean height of the columns is 9·806 diameters. A strongly marked feature in Roman architecture is the stylobate or pedestal for the reception of columns, which was not used by the Greeks. In the examples, it varies in height, but, generally speaking, it is very nearly four diameters of the column; a mean of those used in the triumphal arches comes out at 3·86 diameters. Another difference from Greek architecture is in the form of the Roman pilaster, which was sometimes so strongly marked as to form a sort of square column with capitals and bases similar to those of the columns it accompanies, except in being square instead of circular on the plan. It is diminished in some buildings, as in the portico of the Pantheon, and in that of Mars Ultor, while in others, no such diminution takes place. The reader will recollect that the Greek antæ were never diminished, that their projection was always very small, and that the mouldings of their capitals were totally different from the columns with which they are connected.

266. But the most wonderful change the Romans effected in architecture was by the introduction of the arch; a change which, by various steps, led, through the basilica, to the construction of the extraordinary Gothic cathedrals of Europe, in its progress opening beauties in the art of which the Greeks had not the remotest conception. These matters will be more entered into in the next section: we only have to observe here, that its importançe was not confined to the passage of rivers by means of bridges, but that it enabled the Romans to supply in the greatest abundance to their cities water of a wholesome quality, without which no city can exist. To the introduction, moreover, of the arch, their triumphal edifices were indebted for their principal beauties; and without it their theatres and amphitheatres would have lost half their elegance and magnificence. Whence the arch came is not known. In the section on Egyptian architecture, the subject has already been noticed. We are not aware of any example ornamentally applied before the time of Alexander.

267. The use of coupled columns and niches exhibits other varieties in which the Romans delighted; but the former are not found till an age in which the art of architecture had begun to decline.

268. There is still another point to which the reader's attention must be directed, and it is almost a sure test of Roman or Greek design; namely, the form of the mouldings of an order on their section. In purely Greek architecture, the contours of the mouldings are all formed from sections of the cone, whilst in that of the Romans, the contours are all portions of circles.

269. Under the climate of Rome it became necessary to raise the pitch of their roofs higher than was necessary in Greece; hence the Roman pediment was more inclined to the horizon. As, however, we shall, in another place, when we consider the practical formation of roofs generally, investigate the law which, forced by climate upon the architect, governed the inclination of the pediment, the reader, for further information, is referred, on that point, to its proper place in this work; namely, that wherein the subject of roofs is treated of.

Sect. XIV.

BYZANTINE AND ROMANESQUE ARCHITECTURE.

270. We propose in this section to take a concise view of the state of debased Roman architecture, from the year 476, in which the Roman empire in the West was destroyed, to the introduction of the pointed arch at the latter end of the 12th century. It will be necessary to premise that the term Romanesque is very general, and comprises the works of the Lombards as well as those of a later species, which in this country are called Saxon and Norman, for the character of all is the same, and we think much confusion will be prevented by the arrangement we propose. Between the fifth and the eighth centuries, at the beginning of which latter period the whole of Europe formed one great Gothic kingdom, the prospect is over a dreary desert in which the *oases* of our art are few and far between. The constant change of power, the division of the empire, which was so overgrown that it could no longer hang together, the irruptions of the Goths, whose name has been most improperly connected with all that is barbarous in art, make it no easy task to give the unlearned reader more than a faint idea of what occurred in the extended period through which, often in darkness, we must proceed to feel our way. But, previous to this, we shall continue the state of the architecture in the East; because, having already given some account of Saracenic architecture, which had its origin about the seventh century, we shall not again have to divert his attention from the subject until the reader is introduced to the pointed style: an arrangement which, we trust, will assist his memory in this history.

271. The emperor Theodosius, who died A. D. 395, exhibited great talent in arms, and was desirous to extend the benefit of his influence to the arts, in which he did much for the empire. His sons, Arcadius in the city of Constantinople, and Honorius at Rome, were incapable of doing them any service, though by them was raised the famous Theodosian column at the first named city, which was surrounded with bassi relievi, after the fashion of that erected long before in honour of Trajan at Rome. The ascent of Theodosius II. to the throne promised as well for the empire as for the arts. He called architecture to his aid for embellishing the cities of the empire. Under him, in 413, Constantinople was surrounded with a new wall; some extensive baths, and a magnificent palace for the two sisters of Pulcheria were erected. In 447, an earthquake nearly destroyed the city, which was so admirably restored under this emperor that he might with propriety have been called its second founder. Except some trifling matters under Anastasius II., and Justin his successor, little was done till Justinian, the nephew of the last named, ascended the throne of the East, in 527. By him the celebrated architect Anthemius was invited to Constantinople. Through the genius of this artist, aided by his colleague Isidore the Milesian, on the ruins of the principal church of the city, which, dedicated to Saint Sophia or the Eternal Wisdom, had been twice destroyed by fire, was raised so splendid an edifice, that Justinian is said on its completion to have exclaimed, as Gibbon observes, "with devout vanity:" "Glory be to God, who hath thought me worthy to accomplish so great a work. I have vanquished thee, O Solomon." We shall make no apology for giving the description in the words of the historian we have just quoted; a representation of the building being appended in *figs.* 139. and 140. "But the pride of the Roman Solomon, before twenty years had elapsed, was humbled by an earthquake, which overthrew the eastern part of the dome. Its splendour was restored by the perseverance of the same prince; and in the thirty-sixth year of his reign, Justinian celebrated the second dedication of a temple, which remains, after twelve centuries, a stately monument of his fame. The architecture of St. Sophia, which is now converted into the principal mosque, has been imitated by the Turkish sultans, and that venerable pile continues to excite the fond admiration of the Greeks, and the more rational curiosity of European travellers. The eye of the spectator is disappointed by an irregular prospect of half domes and shelving roofs: the western front, the principal approach, is destitute of simplicity and magnificence; and the scale of dimensions has been much surpassed by several of the Latin cathedrals. But the architect who first erected an *aërial* cupola is entitled to the praise of bold design and skilful execution. The dome of St. Sophia, illuminated by four and twenty windows, is formed with so small a curve, that the depth is equal to only one sixth of its diameter; the measure of that diameter is 115 ft.,

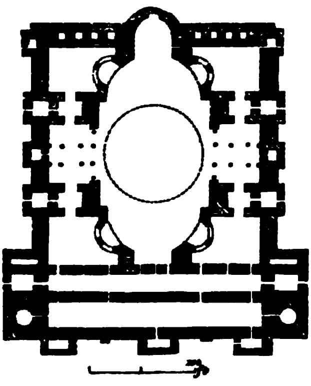


Fig. 139. PLAN OF CHURCH OF ST. SOPHIA.

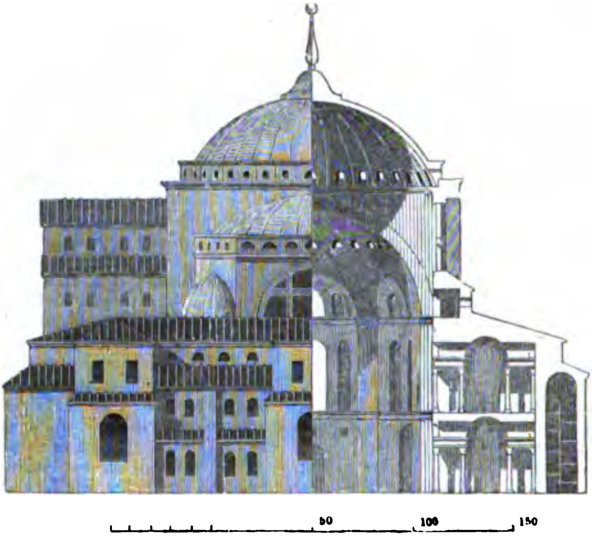


Fig. 140. CHURCH OF SANTA SOPHIA. ELEVATION AND SECTION.

and the lofty centre, where a crescent has supplanted the cross, rises to the perpendicular height of 180 ft. above the pavement. The circle which encompasses the dome lightly reposes on four strong arches, and their weight is firmly supported by four massy piles" (piers), "whose strength is assisted on the northern and southern sides by four columns of Egyptian granite. A Greek cross inscribed in a quadrangle represents the form of the edifice; the exact breadth is 243 ft., and 269 may be assigned for the extreme length from the sanctuary in the east, to the nine western doors which open into the vestibule, and from thence into the *narthex* or exterior portico. That portico was the humble station of the penitents. The nave or body of the church was filled by the congregation of the faithful; but the two sexes were prudently distinguished, and the upper and lower galleries were allotted for the more private devotion of the women. Beyond the northern and southern piles" (piers), "a balustrade, terminated on either side by the thrones of the emperor and the patriarch, divided the nave from the choir; and the space, as far as the steps of the altar, was occupied by the clergy and singers. The altar itself, a name which insensibly became familiar to Christian ears, was placed in the eastern recess, artificially built in the form of a demi-cylinder, and this sanctuary communicated by several doors with the sacristy, the vestry, the baptistery, and the contiguous buildings, subservient either to the pomp of worship or the private use of the ecclesiastical ministers." We should be fearful of thus continuing the quotation, but that we prefer the language of Gibbon to our own; beyond which, the practical knowledge the rest of the description discloses is not unworthy the scientific architect, and the subject is the type of the great modern cathedrals, that of St. Paul, in London, among the rest. "The memory," he continues, "of past calamities inspired Justinian with a wise resolution, that no wood, except for the doors, should be admitted into the new edifice; and the choice of the materials was applied to the strength, the lightness, or the splendour of the respective parts. The solid piles" (piers) "which sustained the cupola were composed of huge blocks of freestone, hewn into squares and triangles, fortified by circles of iron, and firmly cemented by the infusion of lead and quicklime; but the weight of the cupola was diminished by the levity of its substance, which consists either of pumice-stone that floats in the water, or of bricks from the Isle of Rhodes, five times less ponderous than the ordinary sort. The whole frame of the edifice was constructed of brick; but those base materials were concealed by a crust of marble; and the inside of St. Sophia, the cupola, the two larger and the six smaller semi-domes, the walls, the hundred columns, and the pavement, delight even the eyes of barbarians with a rich and variegated picture." Various presents of marbles and mosaics, amongst which latter were seen representations of Christ, the Virgin, and saints, added to the magnificence of the edifice, and the precious metals in their purity imparted splendour to the scene. Before the building was four feet out of the ground its cost had amounted to a sum equivalent to 200,000*l.* sterling, and the total cost of it when finished may, at the lowest computation, be reckoned as exceeding one million. In Constantinople alone, the emperor dedicated twenty-five churches to Christ, the Virgin, and favourite saints. These were highly decorated, and imposing situations were found for them. That of the Holy Apostles at Constantinople, and of St. John at Ephesus, appear to have had the church of St. Sophia for their types; but in them the altar was placed under the centre of the dome, at the junction of four porticoes, expressing the figure of the cross. "The pious munificence of the emperor was diffused over the Holy Land; and if reason," says Gibbon, "should condemn the monasteries of both sexes, which were built or restored by Justinian, yet charity must applaud the wells which he sank, and the hospitals which he founded, for the relief of the weary pilgrims." "Almost every saint in the calendar acquired the honour of a temple; almost every city of the empire obtained the solid advantages of bridges, hospitals, and aqueducts; but the severe liberality of the monarch disdained to indulge his subjects in the popular luxury of baths and theatres." He restored the Byzantine palace; but selfishness, as respected his own comfort, could not be laid to his charge: witness the costly palace he erected for the infamous Theodora, and the munificent gifts, equal to 180,000*l.* sterling, which he bestowed upon Antioch for its restoration after an earthquake. His care was not limited to the peaceful enjoyment of life by the empire over which he presided; for the fortifications of Europe and Asia were multiplied by Justinian from Belgrade to the Euxine, from the conflux of the Save to the mouth of the Danube; a chain of above fourscore fortified places was extended along the banks of the great river, and many military stations appeared to extend beyond the Danube, the pride of the Roman name. We might considerably extend the catalogue of the extraordinary works of Justinian; but our object is a general view, not a history of the works of this extraordinary person, of whom, applying the verses architecturally, it might truly be said —

> Si Pergama dextra
> Defendi possent: etiam hac defensa fuissent; —

and by whom, if architecture could again have been restored, such a consummation would have been accomplished.

272. In 565 Justin succeeded to the throne of the East, after whose reign nothing occurs to prevent our proceeding to the Western part of the empire, except the notice necessary to be taken of Leo the Isaurian, who ordered the statues in the different churches to be broken in pieces, and the paintings which decorated them to be destroyed. Under him Ravenna was left to the Eastern empire, and under his predecessors Mahomet appeared; and in his successors originated the Saracenic architecture described in a previous section. It was under Justin, in 571, that the prophet, as he is called, was born, and was in 632 succeeded by Abubekr.

273. We now return to the empire in the West, whose ruin, in 476, drew after it that of the arts, which had grievously degenerated since the fourth century, at which period their *decadence* was strongly marked. But we must digress a little by supplying a chasm in the history of our art relative to the ancient basilicæ of Rome, the undoubted types of the comparatively modern cathedrals of Europe; and within the city of Rome we shall find ample materials for tracing the origin whereof we speak.

274. The severe laws against the Christians which Severus had passed expired with his authority, and the persecuted race, between A. D. 211 and 249, enjoyed a calm, during which they had been permitted to erect and consecrate convenient edifices for the purposes of religious worship, and to purchase lands even at Rome for the use of the community. Under Dioclesian, however, in many places the churches were demolished, though in some situations they were only shut up. This emperor, as if desirous of committing to other hands the work of persecution he had planned by his edicts, no sooner published them, than he divested himself, by abdication, of the imperial purple.

275. Under Constantine, in the beginning of the fourth century, the Christians began again to breathe; and though that emperor's religion, even to the period of his death, is involved in some doubt, it is certain that his opinion, as far as we can judge from his acts, was much inclined towards Christianity. Out of the seven principal churches, or basilicæ, of Rome, namely, Sta. Croce di Gierusalemme, S. Giovanni Laterano, S. Lorenzo fuori le Murà, S. Paolo, S. Pietro, S. Sebastiano, and Sta. Maria Maggiore, all but the last were founded by Constantine himself. The ancient basilica, which derived its name from *βασιλευς* (a king), and *οικος* (a house), was that part of the palace wherein justice was administered to the people. The building for this purpose retained its name long after the extinction of the kingly office, and was in use with the Romans as well as the Grecians. Vitruvius does not, however, give us any specific difference between those erected by one or the other of those people. In lib. v. c. 1. he gives us the details of its form and arrangement, for which the reader is referred to his work. The name of basilica was afterwards transferred to the first buildings for Christian worship; not because, as some have supposed, the first Christian emperors used the ancient basilicæ for the celebration of their religious rites, but more probably with reference to the idea of sovereignty which the religion exercised, though we do not assert that such conclusion is to be necessarily drawn.

There can be no doubt that the most ancient Christian basilicæ were expressly constructed for the purpose of religion, and their architectural details clearly point to the epoch in which they were erected. These new temples of religion borrowed, nevertheless, as well in their whole as in their details, so much from the ancient basilicæ, that it is not surprising they should have retained their name. We here place before the reader (*fig.* 141.) a plan of the ancient basilica of S. Paolo fuori le Murà, and (*fig.* 142.) an interior view of it, whereby its general effect may be better understood. The latter shows how admirably it was adapted to the reception of an extremely numerous congregation. The numberless columns which the ancient buildings readily supplied were put in requisition for constructing these basilicæ, whereof, adopting the buildings of the same name as the type, they proportioned the elevation to the extent of the plans, and, in some cases, decorated them with the richest ornaments. Instead of always connecting the columns together by architraves on their summit, which might not be at hand, arches were spanned from one to the other, on which walls were carried up to bear the roofing. Though the practice of vaulting large areas did not appear till a considerable time after the building of the first Christian basilicæ, it must be recollected that the Temple of Peace at Rome had previously exhibited a specimen of the profound knowledge of the Romans in the practice of vaulting: in that example, groined vaults of very large dimensions were borne on entablatures and columns. Nor does this knowledge appear to have been lost in almost the last stage of decline of Roman architecture under the emperor Dioclesian. In the baths of this emperor are to be seen not only groined vaults in three

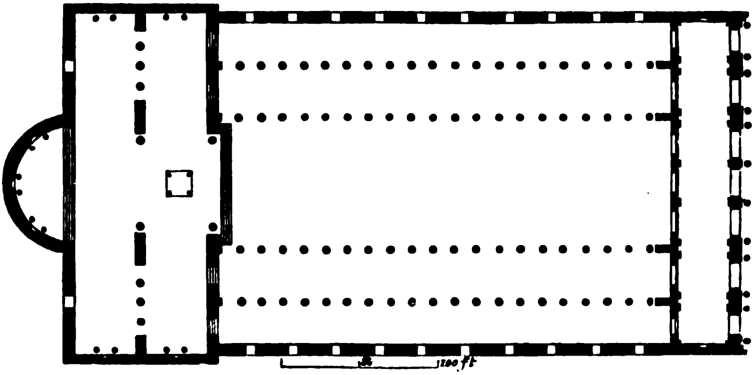


Fig. 141. PLAN OF THE BASILICA OF ST. PAUL.

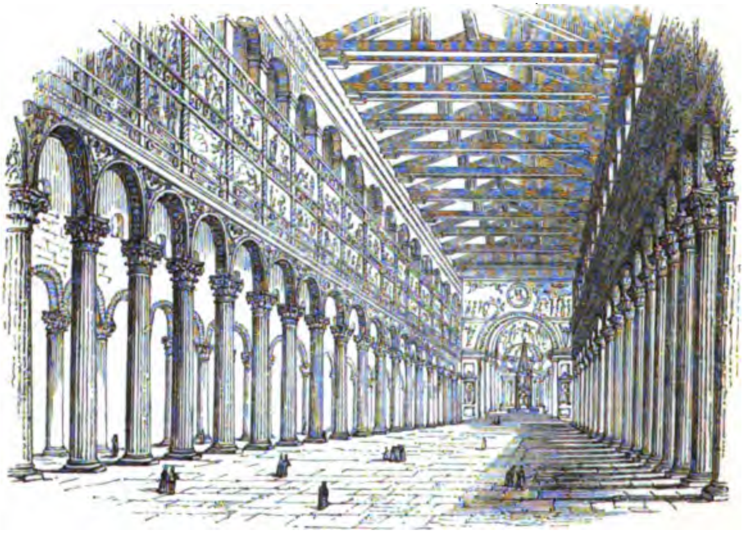


Fig. 142. INTERIOR OF BASILICA OF ST. PAUL.

divisions, whose span is nearly 70 ft., but at the back of each springer a buttress, precisely of the nature of a flying buttress, is contrived to counteract the thrusts of the vaulting.

276. In recording the annihilation of the arts on the invasion of Odoacer, at the end of the fifth and during the course of the sixth century, historians have imputed it to the Gothic nations, qualifying by this name the barbarous style which then degraded the productions of the arts. Correct they are as to the epoch of their ruin, which coincided truly enough with the empire of the Goths; but to this nation they are unjust in attributing the introduction of a barbarous style.

277. History informs us, that as soon as the princes of the Goths and Ostrogoths had fixed themselves in Italy, they displayed the greatest anxiety to make the arts again flourish, and but for a number of adverse circumstances they would have succeeded. Indeed, the people whom the Romans designated as barbarous, were inhabitants of the countries to the north and east of Italy, who actually acquired that dominion and power which the others lost. Instructed at first by their defeats, they ultimately acquired the arts of those who originally conquered them. Thus the Gauls, the Germans, the Pannonians, and Illyrians, had, from their submission to the Roman people, acquired quite as great a love for the arts as the Romans themselves. For instance, at Nismes, the birthplace of Antoninus Pius, the arts were in a state of high cultivation; in short, there were schools as good out of as in Italy itself.

278. Odoacer, son of Edicon, the chief of a Gothic tribe, after obtaining possession of Rome in 476, preserved Italy from invasion for six years; and there is little doubt that one of his objects was the preservation of the arts. He was, however, stabbed by the hand, or at least the command, of his rival and successor, Theodoric, in 493. Theodoric, the son of Theodemir, had been educated at Constantinople, and though personally he neglected the cultivation of science and art, he was very far from insensible to the advantages they conferred on a country. From the Alps to the extremity of Calabria, the right of conquest had placed Theodoric on the throne. As respects what he did for the arts, no better record of his fame could exist than the volume of public Epistles composed by Cassiodorus, in the royal name. "The reputation of Theodoric," says Gibbon, "may repose with confidence on the visible peace and prosperity of a reign of thirty-three years; the unanimous esteem of his own times, and the memory of his wisdom and courage, his justice and humanity, which was deeply impressed on the minds of the Goths and Italians." The residence of Theodoric was at Ravenna chiefly, occasionally at Verona; but in the seventh year of his reign he visited the capital of the Old World, where, during a residence of six months, he proved that one at least of the Gothic kings was anxious to preserve the monuments of the nations he had subdued. Royal edicts were framed to prevent the abuses, neglect, or depredations of the citizens upon works of art; and an architect, the annual sum of two hundred pounds of gold, twenty-five thousand tiles, and the receipt of customs from the Lucrine port, were assigned for the ordinary repairs of the public buildings. Similar care was bestowed on the works of sculpture. Besides the capitals, Pavia, Spoleto, Naples, and the rest of the Italian cities, acquired under his reign the useful or splendid decorations of churches, aqueducts, baths, porticoes, and palaces. His architects were Aloysius for Rome, and Daniel for Ravenna, his instructions to whom manifest his care for the art; and under him Cassiodorus, for fifty-seven years minister of the Ostrogoth kings, was for a long period the tutelary genius of the arts. The death of Theodoric occurred in 526; his mausoleum is still in existence at Ravenna, being now called Sta. Maria della Rotunda. That city contains also the church of St. Apollinaris, which shows that at this period very little, if any, change had been made in the arrangement of large churches on the plan of the basilica. The front of the convent of the Franciscan friars in the same town, which is reputed to be the entrance to the palace, bears considerable resemblance to the Porta Aurea of Dioclesian, at Spalatro. These buildings are all in a heavy debased Roman style, and we are quite at a loss to understand the passage quoted by Tiraboschi, from Cassiodorus, who therein gives a particular description of the very great lightness and elegance of columns; thus—"Quid dicamus columnarum junceam proceritatem? Moles illas sublimissimas fabricarum quasi quibusdam erectis hastilibus contineri et substantiæ qualitate concavis canalibus cavatas, ut magis ipsas æstimes fuisse transfusas; alias ceris judices factum, quod metallis durissimis videas expolitum." (Lib. iii. Epist. 29.) We know no examples of the period that bear out these assertions of Cassiodorus; on the contrary, what is known of this period indicates a totally different style.

279. If the successors of Theodoric had succeeded to his talents as well as his throne, and if they had been assisted by ministers like Cassiodorus, the arts and letters of Italy might have recovered; but, after the retirement of that minister, from the succession of Vitiges, towards 538, the arts were completely extinct. In 543-7, Rome was taken and plundered by Totila; and afterwards, in 553, this ill-fated city was again united to the Eastern empire by the talents of Belisarius and Narses.

280. From the year 568 up to the conquest of Italy by Charlemagne, in 774, the country was overrun by the Lombards, a people who quickly attained a high degree of civilization,

and were much given to the practice of architecture. Maffei, Muratori, and Tiraboschi have clearly proved that neither the Goths nor the Lombards introduced any particular style, but employed the architects whom they found in Italy. Fig. 143. is the west end of the church of St. Michael, at Pavia, a work executed under the Lombards, and, therefore, here inserted as an example of style. The anxiety, however, of the Lombards to preserve the arts was not sufficient to prevent their increasing decay, which daily became more apparent. Not more than the Goths do they deserve the reproach for their treatment of and indifference to them. Besides fortifications and citadels for defence, they built palaces, baths, and temples, not only at Pavia, the seat of their empire, but at Turin, Milan, Spoleto, and Benevento. Hospitals under them began to be founded. The Queen Theodelinda, in particular, signalised her pious zeal in founding one at Monza, near Milan, her favourite residence, and endowing it in a most liberal manner.

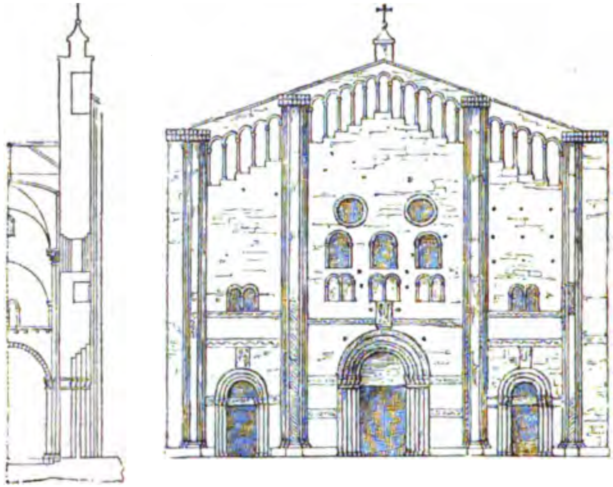


Fig. 143. ST. MICHAEL, PAVIA.

281. In the eighth century the influence of the popes on the fine arts began to be felt. John VI. and Gregory III., at the commencement of the eighth century, showed great solicitude in their behalf. During this age the popes gained great temporal advantages, and their revenues enabled them to treat those advantages so as to do great good for Italy. In the ninth century Adrian I. signalized himself in this passion to such an extent, that Nicholas V. placed on his monument the inscription,—

> Restituit mores, mœnia, templa, Domos.

His works were many and admirable. Among those of great use, he constructed porticoes from the city to San Paolo and S. Lorenzo fuori le Murà.

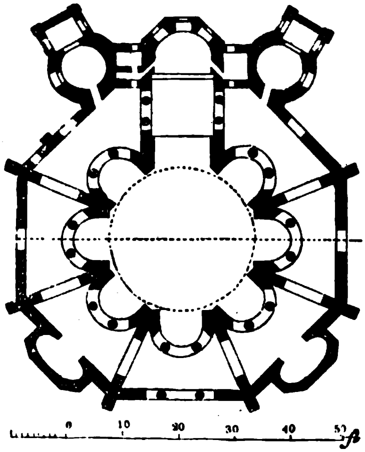


Fig. 144. PLAN OF ST. VITALIS. RAVENNA.

282. Before we advance to the age of Charlemagne, it will be necessary to notice the church of St. Vitalis, at Ravenna, which we have reserved for this place on account of the singularity of its construction. It was erected, as is usually believed, under the reign of Justinian, in the sixth century. See *figs.* 144. and 145. The exterior walls are formed in a regular octagon, whose diameter is 128 ft. Within this octagon is another concentric one, 54 ft. in diameter, from the eight piers whereof (55 ft. in height) a hemispherical vault is gathered over, and over this is a timber conical roof. The peculiarity exhibited in the construction of the cupola is, that the spandrels are filled in with earthen vases; and that round the

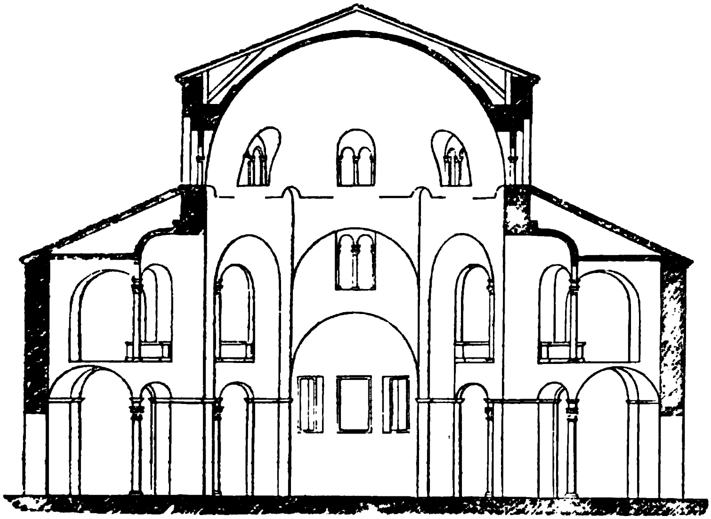


Fig. 145. SECTION OF ST. VITALIS, RAVENNA.

exterior of its base semicircular headed windows are introduced, each of which is subdivided into two apertures of similar forms. Between every two piers hemicylindrical recesses are formed, each covered by a semidome, whose vertex is 48 ft. from the pavement, and each of them contains two windows subdivided into three spaces by two columns of the Corinthian order, supporting semicircular-headed arches. Between the piers and the external walls are two corridors, which surround the whole building, in two stories, one above the other, each covered by hemicylindrical vaulting. The upper corridor above the vault is covered with a sloping or leanto roof. We have before noticed the introduction of vases in the spandrels at the Circus of Caracalla; and we cannot help being struck with the similarity of construction in the instance above cited. It fully bears out the observation of Möller (*Denkmahler der Deutschen Baukunst*), "that, though beauty of proportion seems to have been unappreciated in these ages, and architecture was confined within a servile imitation of the earlier forms, the art of compounding cement, the proper selection of building materials, and an intimate acquaintance with the principles of solid construction with which the ancients were so conversant, were fully understood."

283. The æra of Charlemagne, which opened after the middle of the eighth century and continued into the early part of the ninth, gave rise to many grand edifices dedicated to Christianity. This extraordinary man, rising to extensive dominion, did much towards restoring the arts and civilisation. "Meanwhile, in the south-east," says an intelligent anonymous writer, "the decrepid Grecian empire, itself maintaining but a sickly existence, had nevertheless continued so far to stretch a protecting wing over them [the arts] that they never had there equally approached extinction. It seems probable that Charlemagne drew thence the architect and artisans who were capable of designing and building such a church as the cathedral of Aix-la-Chapelle, in Germany." "If Charlemagne," says Gibbon, "had fixed in Italy the seat of the Western empire, his genius would have aspired to restore, rather than violate, the works of the Cæsars; but as policy confined the French monarch to the forests of Germany, his taste could be gratified only by destruction, and the new palace and church of Aix-la-Chapelle were decorated with the marbles of Ravenna and Rome." The fact is, that the Byzantine or Romanesque style continued, with various degrees of beauty, over the Continent, and in this country, till it was superseded by the introduction of the pointed style. Möller, from whom we extract *fig.* 146. which represents the portico of the Convent of Lorsch, situate about two and a half German miles from Darmstadt, considers it as all that remains of the first church built in the time of Charlemagne. The same learned author observes, that, on comparison with each other of the ancient churches of Germany, two leading differences are discoverable in their styles, of which all others are grades or combinations. The *first*, or earliest, whose origin is from the South, is, though in its later period much degenerated, of a highly finished character, distinguished by forms and decorations resembling those of Roman buildings, by flat roofs, by hemicylindrical vaults, and by great solidity of construction. The *second* and later style still preserves the semicircular forms; but the high pitched roof, more adapted to the seasons

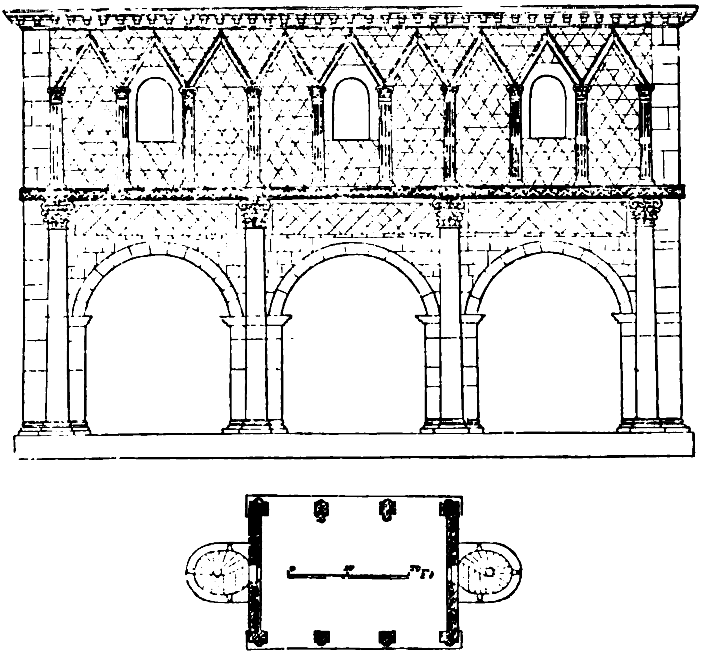


Fig. 146. PORTICO OF LORSCH.

of a northern climate, begins to be substituted for the flat roof of the South, as at the cathedral of Worms on the west side, the western tower of the church at Gelnhausen, and in many other examples.

284. We are now approaching a period in which more light can be thrown on our subject than on that we have just quitted. In the ninth century, on, as it is said, the designs of a Greek artist, rose the cathedral of St. Mark at Venice, the largest of the Italian churches in the Byzantine style. Its plan is that of a Greek cross, whose arms are vaulted hemicylindrically, and, meeting in the centre of the building, terminate in four semicircular arches on the four sides of a square, about 42 ft. in length in each direction. From the anterior angles of the piers, *pendentives* gather over, as in St. Sophia, at Constantinople, and form a circle wherefrom rises a cylindrical wall or drum in which windows for lighting the interior are introduced. From this drum, the principal dome, which is hemispherical, springs. Longitudinally and transversely the church is separated by ranks of columns supporting semicircular arches. The aisles of the nave and choir, and those of the transepts, intersect each other in four places about the centre of the cross, over which intersections are small domes; so that on the roof are four smaller and one larger dome. In the exterior front towards the Piazza San Marco, the façade consists of two stories, in the centre of the lower one whereof is a large semicircularly arched entrance, on each side of which are two other smaller arched entrances of the same form. These have all plain archivolts springing from the upper of two orders of columns. On each flank of the façade is a smaller open arcade springing at each extremity from an upper of two orders of insulated columns. A gallery with a balustrade extends round the exterior of the church, in front whereof, in the centre, are the four famous bronze horses which once belonged to the arch of Nero. The second story towards the Piazza San Marco consists of a central semicircular aperture, with two blank semicircular arches on each side, not quite so high and wide. These five divisions are all crowned by canopy pediments of curves of contrary flexures, and ornamented with foliage. Between each two arches and at the angles a turret is introduced consisting of three stories of columns, and terminated by a pinnacle. The building has been considerably altered since its first construction; and, indeed, the ornaments last named point to a later age than the rest of the edifice, the general character of which has, nevertheless, been preserved. There is considerable similarity of plan between this church and that of St. Sophia.

285. Very much partaking the character of composition of St. Mark, but dissimilar in

general plan, is the church of St. Anthony at Padua, which has six domes over the nave, transepts, centre, and choir. It is, moreover, distinguished by two slender towers or minarets, which impart to it the air of a Saracenic edifice.

286. The Italian architecture in the Byzantine or Romanesque style preserved a very different sort of character from that of the same date in Germany and other parts of Europe. Thus,—taking the cathedrals of Pisa and Worms, whose respective periods of construction are very close together,—the former is separated into its nave and aisles by columns with Corinthian capitals, reminding one very much of the early Christian basilica; in the latter, the separation of the nave from the aisles is by square piers. The cathedral at Pisa, with its baptistery, campanile, and the campo santo or cemetery, are a group of buildings of more curiosity than any four edifices in the world, and the more so from being so strongly marked with the distinguishing features of the Byzantine and Romanesque styles. The cathedral (*fig.* 147.), whose architect was Buschetto of Dulichio, a Greek, was built in the beginning in the 11th century. It consists of a nave, with two aisles on each side of it, transepts, and choir. Its bases, capitals, cornices, and other parts were fragments of antiquity collected from different places, and here with great skill brought together by Buschetto. The plan of the church is a Latin cross; its length from the interior face of the wall to the back of the recess is 311 ft., the width of the nave and four side aisles 106 ft. 6 in., the length of the transept 237 ft. 4 in., and its width, with its side aisles, 58 ft. The centre nave is 41 ft. wide, and has twenty-four Corinthian columns, twelve on each side, all of marble, 24 ft. 10 in. high, and full 2 ft. 3 in. in diameter. From the capitals of these columns arches spring, and over them is another order of columns, smaller and more numerous, from the circumstance of one being inserted over the centre of an intercolumniation below, and from their accompanying two openings under arches nearly equal to the width of such intercolumniations. These form an upper gallery, or *triforium*, anciently appropriated to the use of females. The four aisles have also isolated columns of the Corinthian order, but smaller, and raised on high plinths, in order to make them range with the others. The transepts have each a nave and two side aisles, with isolated columns, the same size as those of the other. The soffit of the great nave and of the transepts is of wood, gilt, but the smaller ones are groined. The height of the great nave is 91 ft., that of the transepts about 84 ft., and that of the aisles, 35 ft. In the centre nave are four piers, on which rest four large arches, supporting an elliptical cupola. The church is lighted by windows above the second order of the interior. The edifice is surrounded by steps. The extreme width of the western front, measured above the plinth moulding, is 116 ft., and the height from the pavement to the apex of the roof is 112 ft. 3 in. The façade has five stories, the first whereof consists of seven arches, supported by six Corinthian columns and two pilasters, the middle arch being larger than the others: the second has twenty-one arches, supported by twenty columns and two pilasters; the third is singular, from the façade contracting where the two aisles finish, and forming two lateral inclined planes, whence in the middle are columns with arches on them as below. The columns which are in the two inclined planes gradually diminish in height: the fifth story is the same, and forms a triangular pediment, the columns and arches as they approach the angles becoming more diminutive. The two exterior sides have two orders of pilasters, one over the other. The roof of the nave is supported, externally, by a wall decorated with columns, and arches resting on their capitals. The whole of the building is covered with lead. The drum of the cupola is externally ornamented with eighty-eight columns connected by arches, over which are pediments in marble, forming a species of crowns. The principal point of difference in these cathedrals from the old basilicæ, in imitation whereof they were doubtless built, is in the addition of the transepts, by which a cruciform plan was given to these edifices. The style of the building in question is much lighter than most of the buildings of the period. But, whatever the taste

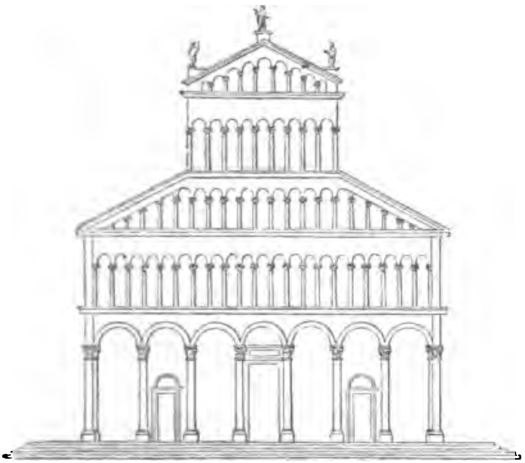
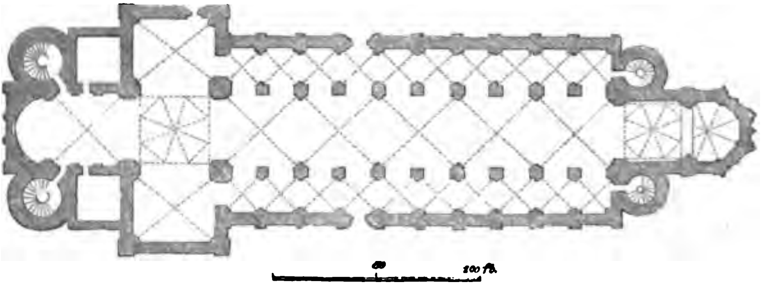


Fig. 147. ELEVATION OF CATHEDRAL AT PISA.

and style, the architect of it was a very skilful mechanic. One of his epitaphs, at Pisa, we subjoin, in proof of what we have stated.

Quod vix mille boum possent juga juncta movere,
  Et quod vix potuit per mare ferre ratis,
Buschetti nisu, quod erat mirabile visu,
  Dena puellarum turba levavit onus.

287. In Germany, the 10th and 11th centuries afford some edifices very important in the history of the art. Such are the cathedrals of Spire, Worms, Mayence, and others, still in existence to testify their extraordinary solidity and magnificence. In that country, as Möller remarks, there was a great disparity between its several provinces, as respected their degrees of civilisation. On the banks of the Rhine, and in the south, cities were established when those parts became subject to the Romans, and there the arts of peace and the Christian religion took root, and flourished; whilst, in the north and east, paganism was still in existence. Christianity, indeed, and civilisation gradually and generally extended from the southern and western parts. The clergy, we know from history, themselves directed the building of churches and convents. The buildings, therefore, of these parts are of great importance in the history of architecture. The leading forms of these churches, as well as of those that were built about the same period in France and England, are founded upon the ancient basilicæ; that is, they were long parallelograms with side aisles, and transepts which represent the arms of the cross, over whose intersection with the nave there is frequently a *louvre*. The choir and chancel terminate semicircularly on the plan. The semicircle prevails in the vaultings and over openings. The nave is lofty, frequently covered with groined vaulting, sometimes with flat timber covering; the gables are of small inclination. In the upper parts small short columns are frequently introduced. The prevailing feature in the exterior is horizontality, by which it is distinguished from the style which came into use in the 13th century. The profiles of the mouldings are, almost without exception, of Roman origin; the impost mouldings under the arches are, in this respect, peculiarly striking; and among the parts the Attic base constantly appears. The Roman basilicæ were always covered with flat horizontal ceilings; those of the churches we are speaking of are mostly vaulted. Hence the necessity of substituting pillars or piers for the insulated columns, which had only to carry wooden roofs. There are, however, a few churches remaining, which preserve the ancient type, as a church at Ratisbon, and the conventual churches of Paulinzell and Schwarzach. *Fig.* 148. shows the plan, and *fig.* 149. a sketch of one bay in a longitudinal section of the north side of the nave of the cathedral at Worms, which was commenced in the year 996, and consecrated in 1016. It is one of the most ancient of the German churches, and one of the most instructive. On our examination of it, recently, we were astonished at its state of preservation. The plan, it will be seen, is strongly distinguished by the cross; the square piers are alternately decorated with half columns; and the chancel, at the east end, terminates with a semicircle. The western end of the church, which is octagonal, appears more modern than the rest, inasmuch as the pointed arch appears in it. *Fig.* 150. is the general appearance of the building.



PLAN OF CATHEDRAL AT WORMS. Fig 148.

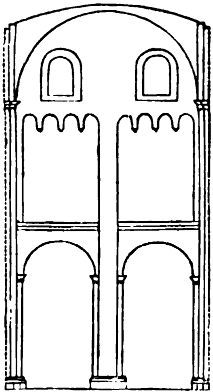


Fig. 149. ONE BAY OF NAVE AT WORMS.

288. Parts of the cathedral at Mentz are more ancient than any part of that at Worms; hence it may be studied with advantage, as containing a view of the styles of several centuries. The south-eastern gate of the cathedral is given by Möller in his work (Plate VI.).

289. Whittington, a highly talented author, of whom the world was deprived at a very early age (*Historical Survey of the Ecclesiastical Antiquities of France*, 4to. Lond. 1809), observes, that the buildings in France of the 9th and 10th centuries were imi-

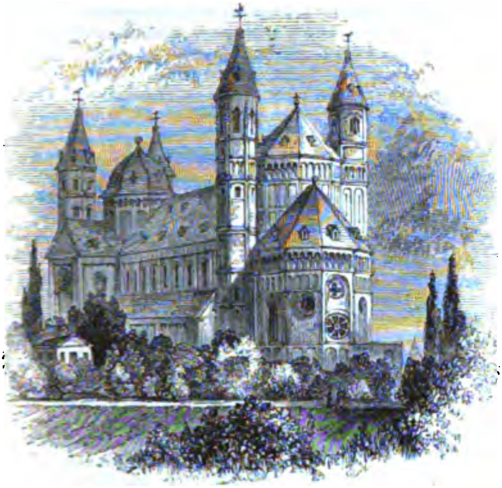


Fig. 150. WORMS CATHEDRAL.

tated from the works of Charlemagne; but that his feeble successors, deficient both in riches and power, were unable to equal them in magnitude or beauty of materials. During a large portion of the 9th century the country was a scene of consternation and bloodshed. The most celebrated, and almost the only foundation of consequence which took place during this dreary period, was the abbey of Clugny. It was built, about 910, by Berno, abbot of Balme, with the assistance of William, Duke of Aquitaine and Auvergne. But there is little doubt that the present church was built in the following century. During the 11th century, the French, relieved from their disordered state, hastened to rebuild and repair their ecclesiastical structures, and their various cities and provinces vied with each other in displays of enthusiastic devotion. Robert the Pious, by his example, encouraged the zeal of his clergy and people; and the science of architecture revived with majesty and effect from its fallen state. Morard, the abbot of St. Germain des Prés, was enabled by this monarch to rebuild the church of his convent on a larger scale. St. Geneviéve was also restored, and a cloister added to it, by his order. He, moreover, made preparations for erecting a cathedral at Paris in a style of as great magnificence as the times would allow. At Orleans, the place of his nativity, he built the churches of Nôtre Dame de bonnes nouvelles, St. Peter, and St. Aignan, which last was consecrated in 1029. But our space does not allow an enumeration of all the works undertaken during his reign. About this time, the cathedral of Chartres was rebuilt by Fulbert, its bishop, whose great reputation, in France and the rest of Europe, enabled him to execute it in a manner till then unknown in his country. Canute, the king of England, and Richard, Duke of Normandy, were among the princes who assisted him with contributions. His successor, Thierri or Theodoric, completed the building. The northern part was afterwards erected in 1060, at the expense of Jean Cormier, a native of Chartres, and physician to the king. The length of the church is 420 ft., its height 108 ft., and the nave 48 ft. wide. The transepts extend 210 ft. The abbey church of Clugny, which succeeded that above mentioned, is one of the largest and most interesting of the ecclesiastical monuments of France, and was begun in the commencement of the 11th century, by the abbot Odilo, and finished by his successor Hugh, in 1069. The ceremony of its dedication did not, however, take place till many years after. The style of architecture in France, in the 11th, was the same as in the preceding centuries; but the churches were larger and more solidly constructed. The oldest buildings of France now existing, with some exceptions, are traceable to this æra; such are the venerable fabrics of St. Germain des Prés, St. Benigne at Dijon, those of Chartres, La Charité sur Loire, Clugny, and others; all remaining to illustrate the history of the arts of this period. But, as we have said before, and to the student the observation cannot be too often repeated, the style which prevailed was no more than a debased and feeble attempt to imitate the ancient architecture of Rome, and its best examples are not, in style even, equal to those of the art in its lowest state under the reign of Dioclesian; indeed the investigation is only important as being one of the means by which we can arrive at a just conclusion on the state of civilisation at different periods. *Mores fabricæ loquuntur* is an expression of Cassiodorus, so true, that to prove it would indeed be lighting the sun with a candle; and we must not trifle with the patience of the reader.

290. The Saxon churches of England, to which and its more modern architecture our succeeding chapter will be entirely devoted, were very inferior in every respect to the Norman churches of France; and these latter differed materially from those in the neighbourhood of Paris, and further to the south. The Norman churches were larger in some examples; but they were more rude in design and execution. The abbey church of St. Stephen, raised at Caen by William the Conqueror, and that founded by his Queen Matilda in the same city in honour of the Holy Trinity, are the chief examples of the peculiar manner of building introduced by the Norman prelates into England at the end

of the 11th century; after which, as we shall presently see, a new and extraordinary style made its appearance in Europe, a style whereof *fig.* 151. will, on inspection, sufficiently give a general notion to the reader.

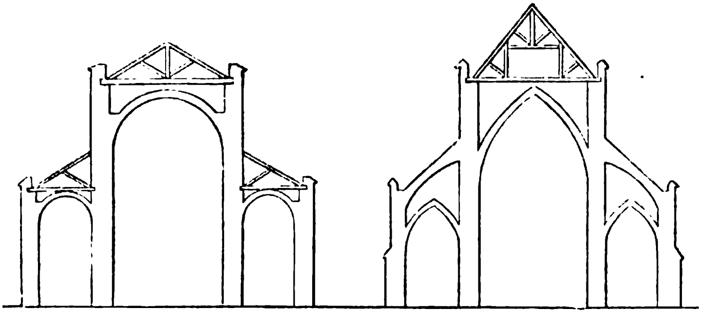


Fig. 151. NINTH TO TWELFTH CENTURY. AFTER TWELFTH CENTURY.

291. Before leaving the subject of this section, we must fall back again upon Italy to notice two or three works intimately connected with this period of the art. We here more particularly allude to the celebrated baptistry and campanile of Pisa, a city which seems to have been a great nursing mother to our art, no less than to those of painting and sculpture. The Campo Santo of that city, of which, from the number of examples to be noticed, we regret we shall be unable to give but a short account, belongs to the next period, and must be noticed after them.

292. Dioti Salvi, whose birthplace even is unknown, commenced, in 1152, the baptistery of Pisa (*fig.* 152.), and after eight years completed it It is close to the cathedral of the place, and though on the wall of the inner gallery there be an inscription, cut in the character of the middle ages, "A. D. 1278, ÆDIFICATA FUIT DE NOVO," and it may be consistent with truth that the edifice was ornamented by John of Pisa, there is nothing to invalidate the belief that the building stands on the foundations originally set out, and that for its principal features it is indebted to the architect whose name we have mentioned. It is 100 ft. in diameter within the walls, which are 8 ft. 6 in. thick. The covering is a double brick dome, the inner one conical, the outer hemispherical. The former is a frustum of a pyramid of twelve sides. Its upper extremity forms a horizontal polygon, finished with a small parabolic cupola, showing twelve small marble ribs on the exterior. The outer vault terminates above, at the base of the small cupola, which stands like a lantern over the aperture. From the pavement, the height of the cupola is 102 ft. The entrance is by a decorated doorway, from the sill of which the general pavement is sunk three steps round the building; the space between the steps and the wall having been provided for the accommodation of the persons assembled to view the ceremony of baptism. An aisle or corridor is continued round its interior circumference, being formed by eight granite columns and four piers, from which are turned semicircular arches, which support an upper gallery; and above the arches are twelve piers, bearing the semicircular arches which support the pyramidal

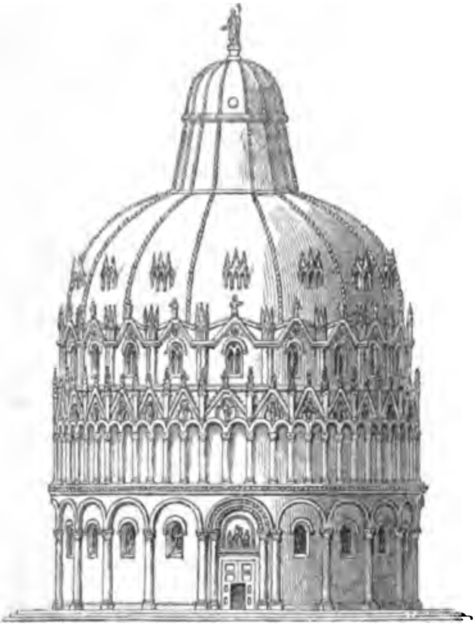


Fig. 152. BAPTISTERY OF PISA.

dome. On the exterior are two orders of Corinthian columns engaged in the wall, which support semicircular arches. In the upper order the columns are more numerous, inasmuch as each arch below bears two columns above it. Over every two arches of the upper order is a sharp pediment, separated by a pinnacle from the adjoining ones; and above the pediments a horizontal cornice encircles the building. Above the second story a division in the compartments occurs, which embraces three of the lower arches; the separation being effected by piers triangular on the plan, crowned by pinnacles. Between these piers, semicircular headed small windows are introduced, over each of which is a small circular window, and thereover sharp pediments. Above these the convex surface of the dome springs up, and is divided by twelve ribs, truncated below the vertex, and ornamented with crockets. Between these ribs are a species of dormer windows, one between every two ribs, ornamented with columns, and surmounted each by three small pointed pediments. The total height is about 179 ft. The cupola is covered with lead and tiles; the rest of the edifice is marble.

293. The extraordinary campanile, or bell tower, near the cathedral at Pisa, was built about 1174. It is celebrated from the circumstance of its overhanging upwards of thirteen feet, a peculiarity observable in many other Italian towers, but in none to so great an extent as in this. There can be no doubt whatever that the defect has arisen from bad foundation, and that the failure exhibited itself long before the building was completed; because, on one side, at a certain height, the columns are higher than on the other; thus showing an endeavour on the part of the builders to bring back the upper part of the tower to as vertical a direction as was practicable, and recover the situation of the centre of gravity. The tower is cylindrical, 50 ft. in diameter, and 180 ft. high. It consists of eight stories of columns, in each of which they bear semicircular arches, forming open galleries round the story. The roof is flat, and the upper story contains some bells. The last of the group of buildings in Pisa is the Campo Santo, which, from its style and date (1278), is only mentioned here out of its place in order to leave this interesting spot without necessity for further recurrence to it. It is the public burying place of the city, and, whether from the remains on its walls of the earliest examples of Giutto, and Cimabue, the beauty of its proportions, or the sculpture that remains about, is unparalleled in interest to the artist. It is a quadrangle, 408 ft. in length, 117 ft. in width, and is surrounded by a corridor 32 ft. in breadth. This corridor is roofed, forming a sort of cloister with semicircular-headed windows, which were at first simple apertures extending down to the pavement, but they have been subsequently divided into smaller apertures by columns, which, from the springing of the arches, branch out into tracery of elegant design. The interior part of the quadrangle is open to the sky. Some of the arches above mentioned were completed as late as the year 1464.

Sect. XV.

POINTED ARCHITECTURE.

294. About the end of the 12th and the beginning of the 13th century, a most singular and important change took place in the architecture of Europe. The flat southern roof, says Möller, was superseded by the high pitched northern covering of the ecclesiastical edifices, and its introduction brought with it the use of the pointed arch, which was substituted for the semicircular one; a necessary consequence, for the roof and vaults being thus raised, the character of the whole could not be preserved without changing the whole arrangement of the combinations of forms. But we have great doubts on Möller's hypothesis; it will, indeed, be hereafter seen we have a different belief on the origin of the pointed arch. Before we at all enter upon the edifices of the period, we think it will be better to put the reader in possession of the different hypotheses in which various writers have indulged, relative to the introduction or invention of the pointed arch; and though we attach very little importance to the discovery, if it could now be clearly established, we are, as our work would be incomplete without the notice, compelled to submit them for the reader's consideration.

295. 1. *Some have derived this style from the holy groves of the early Celts.* — But we can see no ground for this hypothesis, for it was only in the 14th and 15th centuries that ribs between the groins (which have been compared to the small branches of trees) were introduced; hence it is rather difficult to trace the similarity which its supporters contend for.

296. 2. *That the style originated from huts made with twigs and branches of trees intertwined.* — An hypothesis fancifully conceived and exhibited to the world by Sir James Hall, in some very interesting plates attached to his work. Möller properly observes upon this theory of twigs, that it is only in the buildings of the 15th and 16th centuries that the supposed imitation of twigs appears.

297. 3. *From the framed construction of timber buildings.* — This is an hypothesis which it would be loss of time to examine, inasmuch as all the forms and details undoubtedly arise from the vault and arch; and a close examination of the buildings of the 13th century proves that the ancient ecclesiastical style involves the scientific construction of stone vaulting, all timber construction being limited to the framing of the roof.

298. 4. *From the imitation of the aspiring lines of the pyramids of Egypt.* — This hypothesis is the fancy of Murphy, the ingenious and useful editor of a work on the convent of Batalha, in Portugal, and also of some of the finest edifices of the Moors in Spain. The following is the reasoning of the author: — The pyramids of the Egyptians are tombs; the dead are buried in churches, and on their towers pyramidal forms are placed; consequently, the pyramids of the towers indicate that there are graves in the churches; and as the pyramidal form constitutes the essence of the pointed arch style, and the pyramids of the towers are imitations of the Egyptian pyramids, the pointed arch is derived from the latter. The reader, we are sure, will not require from us any examination of the series of syllogisms here enumerated.

299. 5. *From the intersection of semicircular arches which occurs in late instances of the Romanesque style.* — This was the hypothesis of the late Dr. Milner, a Catholic bishop of great learning and most amiable bearing, and a person so intimately acquainted with the subject on which he wrote, that we regret his reasons for the conjecture are not satisfactory to us, albeit the combination (*fig.* 153.) whereof he speaks is, in the Romanesque style, of frequent occurrence. The venerable prelate seems to have lost sight of a principle familiar to every artist — that in all art the details of a style are subordinate to and dependent on the masses, and that the converse never occurs; how, then, could the leading features of a style so universal have had their origin in an accidental and unessential decoration, like that of the theory in question? None of the above hypotheses are satisfactory; and Möller well observes, that the solution of the question, whether the pointed style belongs to one nation exclusively, is attended with great difficulties. And it may be said that the problem for solution is not, who invented the pointed arch, but, in what way its prevalence in the 13th century is to be accounted for.

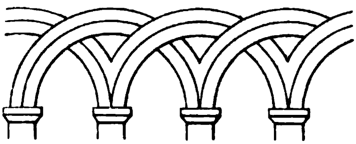


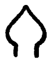
Fig. 153. MILNER'S ORIGIN OF THE POINTED ARCH.

300. We are not of opinion that it is of much importance that this *vexata quæstio* should be settled; and that it will now satisfactorily be done, we consider very much out of the limits of probability. But we suppose that the reader will be inclined to ask for our own bias on the subject; and, as we are bound to answer such a question, the reply is, that we are of the faith of the Rev. Mr. Whittington, to whose work we have before referred, that the pointed arch was of Eastern extraction, and that it was imported by the first crusaders into the West. "All eastern buildings," says that ingenious writer, "as far back as they go (and we cannot tell how far), have pointed arches, and are in the same style; is it not fair to suppose that some of these are older than the 12th century, or that the same style existed before that time? Is it at all probable that the dark ages of the West should have given a mode of architecture to the East?" Lord Aberdeen, whose taste and learning in matters of this nature well qualified him for the posthumous introduction to the public of the author we are using, observes, in his preface to Whittington's work, that, "if we could discover in any one country a gradual alteration of this style [the Romanesque], beginning with the form of the arch, and progressively extending to the whole of the ornaments and general design; — after which, if we could trace the new fashion slowly making its way, and by degrees adopted by the other nations of Europe; — the supposition of Mr. Walpole [that it arose from what was conceived to be an improvement in the corrupt specimens of Roman taste then exhibited, and was afterwards gradually carried to perfection] would be greatly confirmed. Nothing, however, of this is the case. We find the Gothic [pointed] style, notwithstanding the richness and variety it afterwards assumed, appearing at once with all its distinctive marks and features, not among one people, but, very nearly at the same period of time, received and practised throughout Christendom. How will it be possible to account for this general and contemporary adoption of the style, but by a supposition that the taste and knowledge of all on this subject were drawn from a common source? and where can we look for this source but to the East, which, during the crusades, attracted a portion of the population, and, in a great degree, occupied the attention, of the different states of Europe?" This was an opinion of Sir Christopher Wren, at least greatly so, his leaning being rather to deducing the origin of the style from the Moors in Spain. It is the fashion of modern half-educated critics to place little reliance on such authorities as Wren. We have, from experience, learned to venerate them. The noble author whom we have been quoting proceeds by stating that "the result receives confirmation from the circumstance of there being no specimen of Gothic [pointed] architecture erected in the West before the period in question." Exception, however, is to be made for the rare occurrence of a very few examples,

whose construction may perhaps be placed higher than the 12th century, and the cause of whose existence may be satisfactorily explained. "It may be sufficient here to observe, that no people versed in the science of architecture could long remain ignorant of the pointed form of the arch, the most simple and easy in construction, as it might be raised without a centre by the gradual projection of stones placed in horizontal courses; and, whether produced by accident or necessity, we may reasonably expect to meet with it occasionally in their works." It is certain that, though neglected in their general practice, the ancients were acquainted with this mode of building · and the occurrence of an arch merely pointed and unaccompanied with any other characteristic of the style, is no better evidence of the prevalence of Gothic (pointed) architecture, than that the appearance of Corinthian capitals in Romanesque buildings must give them the right to be called classical edifices. It is not easy to answer the question, — In what part of the East are we able to point to buildings constructed in the pointed style, of a date anterior to those erected in the West? A little reflection, however, will solve the difficulty; and here we must again trespass on the author we have so copiously used, though our limits will not allow us to follow him in his own words. It is manifest that the frequent wars and revolutions of the East entailed the same fate on works of art and utility as attended the princes and chiefs of the states subverted. Thus the number of architectural examples, and especially those of early date, was greatly diminished. Again, the people of the East with whom we are best acquainted, in a great measure sacrificed their less durable mode of building to that which they found established by the Greeks. Thus, the church of Santa Sophia was a model, after the conquest of Constantinople, for all the mosques that were erected, with the addition occasionally of minarets more or less lofty, as the piety and magnificence of the sultans might dictate. Previously to the conquest of the metropolis of the East, such a practice was prevalent, and in the cities of the empire many christian edifices were adapted to the purposes of Mohammedan worship. Yet, notwithstanding these causes, which form an impediment to full information on the state of the early architecture of the East, there is an abundance of facts to give probability to our notion, except in the eyes of those who view the subject through the medium of prejudice and established system; at least so we opine.

301. "If a line," says our author, "be drawn from the north of the Euxine, through Constantinople to Egypt, we shall discover in every country to the eastward of this boundary frequent examples of the pointed arch, accompanied with the slender proportions of Gothic [pointed] architecture; in Asia Minor, Syria, Arabia, Persia; from the neighbourhood of the Caspian, through the wilds of Tartary; in the various kingdoms, and throughout the whole extent of India, and even to the furthest limits of China. It is true that we are unable, for the most part, to ascertain the precise date of these buildings; but this in reality is not very important, it being sufficient to state the fact of their comparative antiquity, which, joined to the vast diffusion of the style, appears adequate to justify our conclusion. Seeing, then, the universal prevalence of this mode in the East, which is satisfactorily accounted for by the extensive revolutions and conquests effected by Eastern warriors in that part of the world, it can scarcely appear requisite to discuss the probability of its having been introduced from the West, or, still less, further to refute the notions of those who refer the origin of the style [as some have very ignorantly done] to the invention of English artists. Had it been adopted from the practice of the West, such a peculiarity of taste and knowledge must have been imparted by some general communication: this has only occurred at one period, during which no building of the species in question existed in Europe. The inhabitants of the West could not convey a knowledge which they did not possess; but, as it became pretty general amongst them shortly after the epoch alluded to, it is reasonable to infer that they acquired it from those nations they are said to have instructed. On the whole, it is probable that the origin of the Gothic style, notwithstanding the occasional imitation of a corrupt and degraded species of Roman architecture, is sufficiently indicated by the lofty and slender proportions, by the minute parts, and the fantastic ornaments of Oriental taste."

302. Möller, a writer for whose opinions we entertain the highest respect, is not, however, of opinion that the pointed arch originated with the Arabs; and he observes that a scrutiny of their buildings will exhibit nothing that bears upon the Gothic, or pointed, style. He says that their arches are in the shape of a horseshoe; that the columns are low, that they stand single, and are not connected in groups; that the windows are small, the roofs flat, and that the prevalent general forms are horizontal: that, in the ancient churches of the 13th century, the arches are pointed, the pillars high and composed of several columns, windows large, and roofs and gables high. But at the end of his argument he admits that the solution of the question, "which of the European nations first introduced or improved the pointed style is not so easy, for we find this style of building almost contemporary in all parts of Europe." Now, though we are not about to use the argument which is not always valid, *post hoc ergo propter hoc*, we must observe, that the introduction of the pointed arch immediately after the first Crusade, and not before, is a most singular occurrence; and we are inclined to give it the same force as that used by old Bishop



Latimer on the subject of the Goodwin Sands and Tenterden steeple. One of the points of Möller's reasoning we do not think at all fortunate; it is that on the forms of the Moresque arches. Now, it must immediately occur to the reader that one of the forms (as at the side), and that a common one, is to be found in their arches, that of contrary flexure; a form in the architecture of this country in the time of the Tudors universally adopted, though, it must be allowed, much flattened in the application. Another point seems to have been altogether overlooked by Möller, namely, the practice of *diapering* the walls, whereof an instance occurs in Westminster Abbey; and one which has a very strong affinity to the practice of the Moors, who left no space unornamented. The higher-pitched gables of the northern roofs, we admit, fostered the discovery, by the introduction of forms from necessity, which were admirably calculated to carry out to their extreme limits the principles of which the Crusaders had acquired some notion for practice on their return to their respective countries. As to the objection that the Arabs had no original architecture, it is admitted. They must, however, have had that of the tent, whose form inverted would give all that is sought. These observations we do not throw out, however, as partisans; because, as we have before said, the satisfactory settlement of the origin involves nothing more than a silly antiquarian controversy, of importance to no one, and, if decided, gratifying only to little minds; and we ought, perhaps, to apologise, under such circumstances, to the reader, for having so long delayed his entry to the acquaintance with its examples. We cannot, however, proceed to that part of our duty without observing that the hypothesis adopted by us is sanctioned, in addition to the intelligent author upon whom we have drawn so much, by Warburton, and T. Warton, and Sir Christopher Wren; and though none of these had the opportunity of basing their opinions upon the labours of the recent travellers whom we have been able to use, we do not think, upon this mooted question, either of them would be reduced to the necessity of retracting what he has respectively written. The reader who is inclined to read the lucubrations of Mr. Kerrich of Cambridge, which deduce the forms of churches, arches, and perhaps many other objects, from the bladder of a fish (vesica piscis), may consult the Archæologia; in which, as respects that subject, much money was uselessly and ridiculously expended in text and plates, to illuminate the world on a subject whereof the writer was most profoundly ignorant, a remark which will equally apply to later writers on the subject who have appeared from that seat of learning. We do not think we underrate the number of writers on the subject of the origin of the pointed arch, when we state that it amounts to sixty, a majority of whom never saw a pointed arch out of their own country, England; and therefore persons, from actual comparison and knowledge, totally incapacitated from estimating the very nice distinctions and grades by which the truth could be eliminated.

303. The golden age of pointed architecture was from the middle of the 13th to the latter end of the 14th century, and one of the first churches in which it appeared, so as to allow it to be quoted as a fair specimen of the style, is that of Gelnhausen, in Swabia, an edifice which, it may safely be said, rose in the beginning of the 13th century. On the plan it is a Latin cross, terminating in three sides of an octagon at the eastern end, where it is flanked by two octagonal towers with plain buttresses at the angles. There is a similarity in the long narrow windows at the eastern extremity to those of the churches of Constantinople; but they are sharply pointed like the end of a lancet, and, from the circumstance, are universally denominated lancet-headed windows. Over these windows are ornamental semicircular recesses; and again above these is a tier of small columns attached to the wall which support arches of *trefoil* formation. In the wall between the columns *quatrefoil* windows are introduced inscribed in circles, and above the arcade each face of the octagon is pierced with a small window of two apertures, both ending in trefoil heads. Each side is crowned by a rectilinear gable, under whose sloping sides occurs the *nebule* or wavy ornament, bearing some resemblance to small arcades, with their imposts rounded. The octagon is crowned generally by a lofty pyramidal roof, without ornament. The two towers on the flanks are divided horizontally, by means of rectangular panels, into five horizontal parts, each of them at the upper part being decorated with small semicircular corbel-formed ornaments. The faces are crowned by small pediments, and the tower is terminated by a plain pyramidal spire. The central tower of the edifice is octagonal on the plan, containing two tiers of windows; whereof those in the lower tier have some double, others triple, apertures, formed by *mullions*, over which are trefoil heads; whilst those in the upper tier have double apertures with pointed heads. The central opening of the three-light windows in the lower tier rises above those on the sides; but they are enclosed under one semicircular arch. This tower is also crowned with a simple pyramidal spire.

304. The beautiful church at Oppenheim, dedicated to St. Catherine, is, like that just described, a Latin cross on its plan, and consists of a nave and transepts. Its chancel is five sides of an octagon. As in many of the churches of Germany, it has a second chancel for the canons at the western extremity, terminating in three sides of an octagon. The entrances are on the north and south sides of the transepts. From a MS. chronicle of the church, quoted by Möller, it is ascertained that the nave and

eastern chancel were begun in 1262, and finished in 1317. The western chancel was not consecrated till 1439. The total length of the church, including the two chancels, is 268 ft.; whereof the western chancel, whose breadth is 46 ft., occupies 92 ft. The nave is 102 ft. in length, and its breadth 86, that breadth comprising the two side aisles which are separated from the nave by clustered columns. The transept is 102 ft. long, and 31 ft. broad. In the side aisles are small chapels. In the western front, at the extremity of the nave, are two towers, standing on square bases, each of four stories, and crowned by an octagonal spire. In their three upper stories are round-headed windows, which, where double, are separated by pilasters. The windows of the aisles occupy the whole space between the buttresses, are without mullions, and have pointed arches. The buttresses, whose faces are ornamented with panels, are without pinnacles. The upper windows are surmounted by rectilinear pediments, with crockets and slender pinnacles between them. The doorway of the south transept is with a pointed arch, having one lancet-headed window above. The transept terminates in a gable, within which seven small pediments are placed. Buttresses are placed at the angles of the transepts terminating in pinnacles. Buttresses without pinnacles flank the angles of the hemi-octagon at the east end, whose sides are pierced with lancet-headed apertures. In the western façade is an elegant rose window of twenty small leaves in groups of five. Over the intersection of the transepts with the nave stands an octagonal tower, in each face of which is a pointed window. The centre is covered with a small cupola. On a visit to this beautiful church about four years since, we were pleased to find it under repair, and likely to be preserved.

305. The two churches of Germany whose fame makes it necessary to notice them here are those of Strasburg and Cologne. The first was begun in 1277, by Erwin de Steinbach, and was carried on under various architects till 1439, since which nothing has been done towards its completion. Among the examples of pointed architecture, this is the most stupendous. There is a similarity of style between it and the cathedrals of Paris and Rheims, except that the ornaments are more minute. The plan is a Latin cross, whose eastern end terminates interiorly in a semicircle, but on the exterior in a straight line. The length of the church is 324 ft., that of the transept 150 ft.: the height of the vault is 98 ft. The nave has one aisle on each side of it. The western façade is in three vertical divisions separated by buttresses. In the central one is the principal portal, and thereover, we believe, the largest rose window in Europe. The portal just mentioned, as well as that on each side, has a rectilinear pediment highly decorated. The sides and sofites of the portals are filled with canopies and statues. The two stories of windows above the ground are pointed; those in the first story having slender bar divisions in front of them, and those above being subdivided into three parts by a species of thin buttresses. On the north side of the façade, being the north-west angle of the edifice, rises the spire, whose height has been so variously represented, that some authors have made it 100 ft. higher than others: we believe the correct height to be 466 ft., being greater than that of any church in Europe. To a certain height the tower is square and solid, being formed by one of the vertical divisions of the western façade. Above the solid part, the tower rises to a certain height octangularly, open on all sides, and flanked by four sets of open spiral staircases, which are continued to the line whence the principal tower rises conically in seven stories or steps, crowned at the summit with a species of lantern. In the interior of this church, near one of the large piers of the transept, is a statue of the architect Erwin, in the attitude of leaning over the balustrades of the upper corridor, and looking at the opposite piers. John Hültz of Cologne succeeded Erwin as architect of the fabric: he continued the tower which we have just described, and which was only finished in 1449.

306. We propose to close our view of the pointed architecture of Germany with some short account of that which, had it been completed, would have been the most magnificent and exquisitely ornamented ecclesiastical edifice the world ever saw, we mean the cathedral at Cologne, whose plan (*fig.* 154.) exhibits a symmetry not surpassed by the buildings of ancient Greece and Rome. A church had been erected on the present site of this cathedral in the time of Charlemagne. This was destroyed by fire in 1248, at which time Conrad filled the archiepiscopal throne of the city. Before fire had destroyed the former cathedral, this prelate had resolved on the erection of a new church, so that in the year following the destruction of the old edifice, measures had been so far taken, that the first stone of the new fabric was laid with great solemnity on the 14th of August, being the eve of the Assumption of the Blessed Virgin. Collections were made throughout Europe for carrying on the works, and the wealth of Cologne itself seems to have favoured the hope that its founder had expressed of their continuation. The misfortunes of the times soon, however, began to banish the flattering expectation, that the works would be continued to the completion of the building. Gerard, who was the architect of the works in 1257, suffered the grief of seeing the archbishops of Cologne dissipate their treasures in unprofitable wars, and ultimately abandoning the city altogether for a residence at Bonn. The works do not, however, appear to have been interrupted, though they proceeded but slowly. On the 27th of September, in the year 1322, seventy-four years after the first

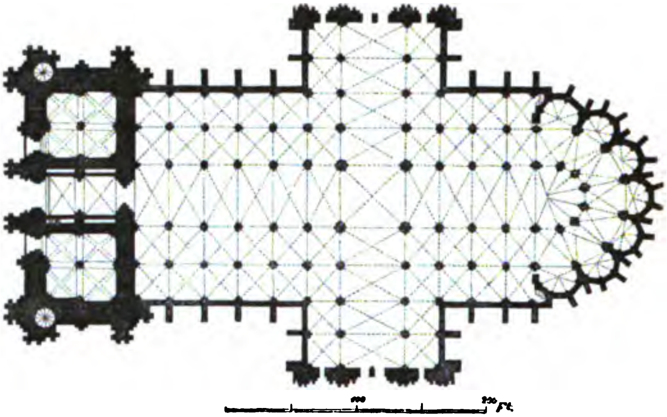


Fig. 154. PLAN OF COLOGNE CATHEDRAL.

stone had been laid, the choir was consecrated. The works were not long continued with activity, for about 1370, the zeal of the faithful was very much damped by finding that great abuses had crept into the disposal of the funds. The nave and southern tower continued rising, though slowly. Under Thierry de Moers in 1437, the latter had been raised to the third story, and the bells were moved to it. In the beginning of the 16th century, the nave was brought up to the height of the capitals of the aisles, and the

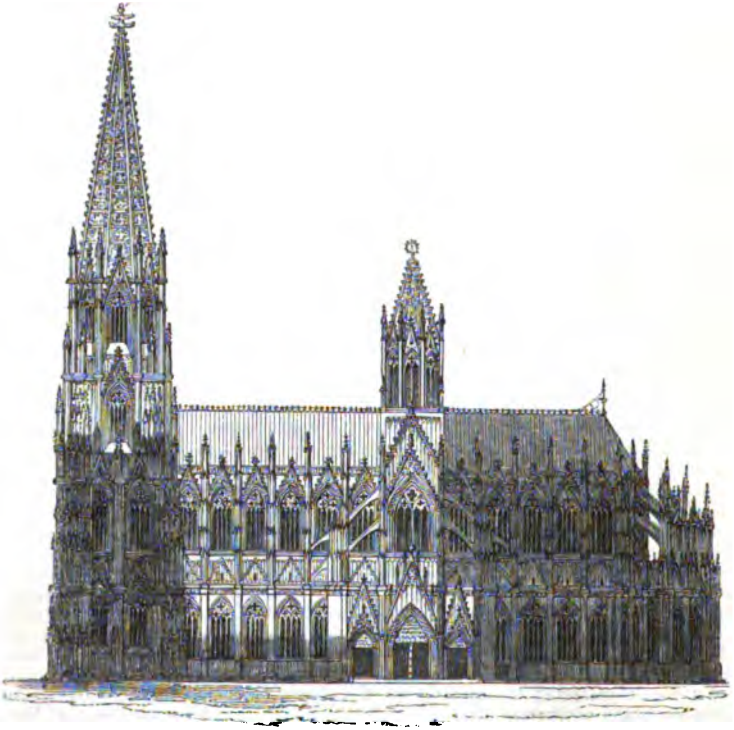


Fig. 155. SOUTH ELEVATION OF COLOGNE CATHEDRAL.

vaulting of the north aisle was commenced; the northern tower was carried on to the corresponding height; and every thing seemed to indicate a steady prosecution of the work, though the age was fast approaching in which the style was to be forgotten. The windows in the north aisle were decorated, though not in strict accordance with the style, yet with some of the finest specimens of painted glass that Europe can boast, a work executed under the patronage of the archbishop Hermann of Hesse, of the chapter, of the city, and of many noble families who are, by their armorial bearings, recorded in these windows. But with this the progress stopped. The works which remain are at once a monument of the genius which conceived such an edifice, and of the civil discords that prevented its completion. *Fig.* 155. exhibits the south elevation of the cathedral, in which the darker lines show the parts actually executed, and the lighter ones those which remain, alas! still to be developed in matter. If the reader reflect on the dimensions of this church, whose length is upwards of 500 ft., and width with the aisles 280 ft.; the length of whose transepts was 290 ft. and more; that the roofs are more than 200 ft. high, and the towers when finished would have been more than 500 ft. on bases 100 ft. wide; he may easily imagine, that, notwithstanding all the industry and activity of a very large number of workmen, the works of a structure planned on so gigantic a scale, could not proceed otherwise than slowly, especially as the stone is all wrought. The stone of which it is built is from two places on the Rhine, Koenigswinter and Unckel-Bruch, opposite the Seven Mountains, from both of which the transport was facilitated by the water carriage afforded by the Rhine. The foundations of the southern tower are known to be laid, at least, 44 ft. below the surface.

307. The states of Europe ought to contribute towards the completion of this stupendous work, which the aid, liberal as it is, of the King of Prussia, does little more than keep in repair; though at this moment there is a complete staff of architect, clerks of works, masons, &c., constantly employed on the fabric. We subjoin a table of the receipts and expenditure upon it in the ten years from 1824 to 1833 inclusive, by which it will be seen how alive, among the sovereigns of the Continent, the late King of Prussia was to the importance of the arts.

Years.	Royal Grant from the Public Treasury in	Produce from Sale of old Materials.			Amount of Contributions towards the Edifice.			Amount of Collections.			Amount of Presents.			Total Receipts.			Total Expenditure.		
	Rix dollars.	*R. D.*	*Silb. g.*	*Pf.*	*R. D.*	*Silb. g.*	*Pf.*	*R. D.*	*Silb. g.*	*Pf.*	*R. D.*	*Silb. g.*	*Pf.*	*R. D.*	*Silb. g.*	*Pf.*	*R. D.*	*Silb. g.*	*Pf.*
1824 1825	35084	361	19	1	-	-		-	-		-	-		35445	19	1	31050	29	11
1826	15000	47	23	0	3998	28	8	-	-		-	-		19046	21	8	16930	21	9
1827	15000				4009	5	2	-	-		-	-		19009	5	2	20743	5	9
1828	15000	117	11	8	3882	21	1	-	-		-	-		19000	2	9	23229	12	0
1829	15000	149	15	0	3966	0	0	-	-		-	-		19115	15	0	19027	27	4
1830	10000	146	20	0	4953	0	0	565	8	0	-	-		15664	28	0	15924	4	4
1831	10000	116	28	4	5750	26	5	4729	26	4	26	8	7	20623	20	8	16685	10	9
1832	10000	175	2	0	5771	8	2	3035	28	6	18	21	6	19001	0	2	18375	17	10
1833	10000	209	16	0	6010	8	8	6	14	0	11	24	6	16238	3	2	22955	13	11
	135084	1324	15	1	38342	8	2	8337	16	10	56	24	7	183145	4	8	184922	23	18

308. So that the average yearly expenditure, for the ten years above named, amounts to 2716*l.* sterling, a sum manifestly little more than necessary for keeping the building in repair, and leaving us without the most distant prospect of its ever being more than preserved. The above table is extracted from the small brochure by M. J. De Noel, published at Cologne in 1835.

309. The cathedral at Ulm (*fig.* 156.) is another of the many celebrated cathedrals of Germany: it was commenced in 1377, and finished, the tower excepted, in 1478. It is reputed to be the longest church in Germany, being 416 ft. long, 166 ft. wide, and, including the thickness of the vaulting, 141 ft. high. The piety of the citizens of Ulm moved them to the erection of this structure, towards which they would not accept any contribution from foreign princes or cities; neither would they accept any remission of taxes nor indulgences from the pope. The whole height of the tower, had it been finished according to the original design (still in existence), would have been 491 feet. It does not preserve the regularity of form for which the cathedral at Cologne is conspicuous, but the composition of it, as a whole, is exceedingly beautiful. At Ratisbon is another beautiful work, of about

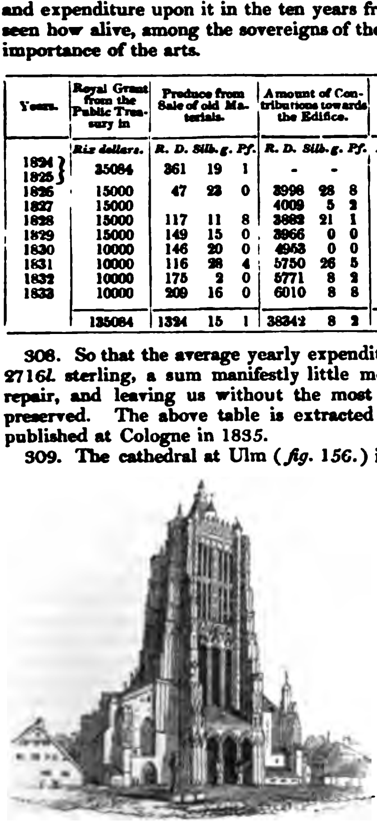


Fig. 156. ULM CATHEDRAL.

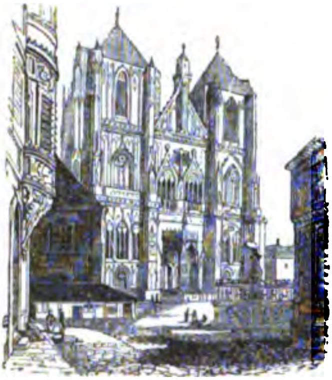


Fig. 157. RATISBON CATHEDRAL.

the same period, of which *fig.* 157. is a sketch; but we do not think it necessary to detain the reader with the description of it. At Vienna the cathedral of St. Stephen's exhibits another exquisite example of the style.

310. We have mentioned a few of the churches of France in the Byzantine or Romanesque styles. In the thirteenth century the pointed style there reached its highest excellence. "Every thing," observes Whittington, "seemed to conspire, in the circumstances of the nation and of the world, to produce an interval favourable for the cultivation of the arts; and genius and talents were not wanting to make use of the happy opportunity. The thirteenth century found the French artists, a numerous and protected body, in possession of a new and beautiful style of building; the religious enthusiasm of the times, fanned by the spirit of the Crusades, was at its height, and the throne of France was filled by monarchs equally distinguished by their piety and magnificence." The chronicle of the abbey of Bec in Normandy informs us that Ingelramme, who had been employed on the church of Notre Dame at Rouen, was, in 1212, engaged on the church of this Norman abbey, a great portion whereof he raised in a year and a half, and in which he was succeeded by Waultier de Meulan, who finished the work in less than three years. Little of this building remains, from the circumstance of its having been burnt twice within the century, and renewed in its present form about 1273, by the Abbot de Caniba. At this period the churches of France were rising in every direction. At Rheims, the cathedral (*fig.* 158.) exhibited the elegant lightness of the new style; the body of the cathedral at Lyons was completed; the exquisite cathedral of Amiens (*fig.* 159.) was raised by Robert de Luzarches and his successors; and, among many other architectural beauties, the Sainte Chapelle of the palace at Paris. Neither must we omit the celebrated Eudes de Montreuil, among whose numerous works, after his return from the East, whither he had accompanied St. Louis, was the church of Notre Dame de Mantes, the boldness of whose vaulting astonished Soufflot and Gabriel in their scientific survey of the French churches, and of which it is related, perhaps fabulously, that when the building was finished, the workmen refused to remove the centering, until Eudes, by sending his nephew to assist them, quieted their apprehensions. The height of the vaulting from the pavement is 96 feet. This Eudes died in 1289, and of his two wives, Mahault, or Maud, attended the queen on her voyage to Egypt and the Holy Land. Another artist, Jousalin de Courvault, is known to have accompanied the king (St. Louis) to the crusade. The number of ecclesiastical structures in France erected during the reign of St. Louis exceeds all former and subse-

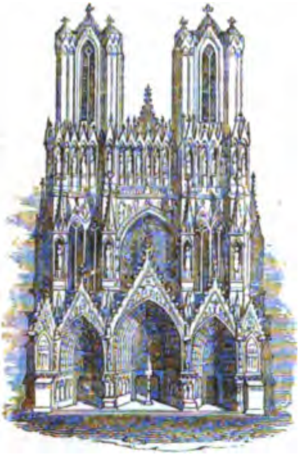


Fig. 158. RHEIMS CATHEDRAL.

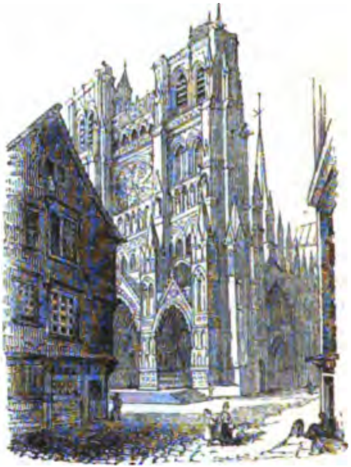


Fig. 159. AMIENS CATHEDRAL.

quent example. Besides a great number founded by individuals, the church and abbey of St. Antoine near Paris, those of the Filles Dieu, the Jacobins, the Carmelites, and the Cordeliers du Faubourg St. Marcel, were built by command of the king; and, out of the metropolis, the abbeys of Lis near Melun, of Longchamp near St. Cloud, and St. Mathieu near Rouen; the greater part of the abbey of St. Denis; the Hotels Dieu of Vernon, Pontoise, and Compiegne; the church and abbey of Maubuisson; the church of the nuns of Poissy, and the monastery and church of Royaumont by Pierre de Montereau, are recorded as the monuments of this munificent sovereign. At the latter end of the twelfth, or in the beginning of the thirteenth, century, moreover, sprung up a brotherhood, known by the name of the *Confraternité des Ponts*, founded by St. Benezet, to which belongs the honour of having erected a bridge across the Rhone at Lyons in 1244, and the Pont St. Esprit, another vast structure. The first stone of this was laid with great ceremony in 1265 by Jean de Tianges, prior of the monastery of St. Esprit, and the whole structure, above 3000 feet in length, was completed in 1309. The building of bridges and maintaining of roads at this period may be almost deemed to have been as great an act of piety as the founding of churches; and a religious association for such a purpose affords a proof of the previous barbarism and increasing civilisation of the age.

311. The wars carried by the English into the very heart of France, as well as the factions and divisions of the French nobility, put a stop to the cultivation of the fine arts, and the fine pointed style of this country ceased about the fourteenth century. The two succeeding ones were not distinguished by architectural efforts of excellence equal to those whereof we have been speaking. Before the invasion, however, of Edward III. and in the provinces at a distance from the scene of warfare, the earlier part of the fourteenth century produced some beautiful churches, among which was that of St. Ouen at Rouen, a work celebrated no less for the beauty of its composition than for the remarkable skill and delicacy exhibited in its execution. It was begun under the abbot, Jean Marc d'Argent in 1318, but not finished till near the middle of the following century. Under Charles V., whose valour and policy procured for France a more favourable aspect in the affairs of the country, many buildings of importance were undertaken and completed. The principal edifices, however, of this monarch were of a nature civil and military rather than religious. The Bastile and the castle of Vincennes were finished by him; in the latter whereof he founded, about 1379, a very beautiful chapel, on the model of the Sainte Chapelle at Paris. The Châtelet, the walls of the city near the Porte St. Antoine, the châteaux of St. Germain en Laye, Montargis, and Creil, were constructed by him, as also many improvements and additions at the Louvre. Charles VI. was more interested in preparations for the invasion of England than in the patronage of architecture: he nevertheless caused the erection of the abbey of Bonport and some other edifices.

312. Though in the fourteenth century the style of the thirteenth did not altogether disappear, its character gradually altered, especially in the continuation of the mullion work over the heads of the windows, which, from being ornamented with six foils or roses, were now branched out into the form of leaves; and the compartments of the circular windows in transepts, and at the end of naves, underwent a great change in their composition, often extremely fanciful. The vaultings of the roofs, too, were much more highly decorated. All these alterations took place at nearly the same period, or a short time after, in England, whose prosperity then enabled the artist to carry them to a much higher state of perfection and magnificence, as will hereafter be shown.

313. The fifteenth century was not more favourable to the practice of architecture in France than the fourteenth had been. It produced few buildings, nor was it indeed probable that any of grandeur and importance could have been undertaken and carried on during the constant and sanguinary contests which concluded with the expulsion of the English from its shores, by which the monarchy from its most abject degradation was once more restored to vigour and prosperity. "The architectural taste of this age," says the author whom we have so much quoted, "resembled the contemporary style of England and other countries. Many instances of tracery may be remarked, especially in sepulchral monuments and chapels; but the distracted condition of France afforded little leisure to her inhabitants for works of piety and genius; and prevented them from adding to the sumptuous structures of their ancestors any great example of that superlative beauty or richness which characterise the architecture of England at this period." The time, in fact, had arrived when it was to be superseded altogether by the disposition which soon became universal in Europe for returning to an imitation of the works of the ancients, which, begun by the artists of Italy, was soon carried into every other country where civilisation had a footing.

314. Our notice of pointed architecture in France we shall close with a short notice of the cathedrals of Rheims and Amiens, which, with Mr. Whittington, we are of opinion are two of the finest examples of the style in the world. The former, which was not quite finished till 1440, is in the form of a Latin cross on the plan; its length from east to west is 492 ft., and its breadth, measured to the extremities of the arms of the transepts, is

190 ft. The interior is divided longitudinally into a nave and choir with side aisles. The width of the transepts is 98 ft., which is equal to that of the body of the church; and the transepts, like the nave and choir, have their side aisles. The western front is composed, as usual, with three entrances, the centre one being the largest; the three being crowned with pointed arches and high pediments with their crockets and finials. The buttresses of the front rise between these pediments, terminating in slender pinnacles. Over the centre door is a very magnificent circular window, with radiating mullions, terminated at the circumference by pointed arches. Over each side portal rises a square tower, decorated in the first story with windows, and in the second with a canopy which extends horizontally throughout the façade; the height of the towers being 270 ft. from the ground. The portals are of the most superb description, the sofites of the arches being masses of canopy work, exquisitely formed and elaborately finished. This work was planned and begun in 1215, at which time the pointed architecture of England was by no means so advanced towards perfection as it was on the Continent, the cathedral of Salisbury having been commenced 15 years later.

315. The cathedral of Amiens has always been the admiration of travellers, and " claims," says Whittington, " our attention, as it seems to throw a very strong light on the history of that style, which has so long been, and probably will continue to be, distinguished by the contemptuous epithet [Gothic] it at present bears." The date of the cathedral of Amiens having been correctly ascertained, and nearly coinciding with that of Salisbury, it is fair to compare the contemporary styles from these two examples. They were begun in the same year 1220, and the original plans in both were carried through without mixture of the styles that succeeded before their completion. We entirely agree with Whittington, that of the two, Amiens is in a more perfect and advanced state of art than Salisbury, and that the French were before us in adding to the simple beauties of the former period many graces which we did not adopt till the latter. In England the prominent feature of the thirteenth century was the highly pointed arch, struck from two centres, and including an equilateral triangle from the springing to the crown or apex of the arch; and another, as Bentham (*Hist. of Ely*) well observes, is the employment of Purbeck marble pillars, very slender, and encompassed by marble shafts, a little detached, and a profusion of small columns of the same stone in the ornamental parts of the building. These peculiarities are found in Amiens, the arches of whose aisles resemble those of Salisbury and Westminster, as do the pillars. The vaulting, moreover, is like that of Salisbury. In plan, proportion, and ornament, however, the general character of the building differs very materially. As respects the first, the aisles to the transepts, the double ones on each side of the choir whose end is so beautifully terminated by a semicircular colonnade, are differences from Salisbury; the number of columns, too, exceeds that used in our churches of the same date, and produces an infinitely richer effect. The dissimilarity is continued in the proportions of the whole cathedral, and especially in the height in relation to the width, that of the pillars to the width of the arches, and in many other details. It is nevertheless in the ornamental part that the chief difference exists, and most particularly in the hosts of saints, prophets, martyrs, and angels, which line the doors, cover the walls, and cluster round the pinnacles. There is nothing in the church of Salisbury which approaches this. We have not, however, space to pursue the subject, and shall therefore close it with a comparison of the respective dimensions of the French with the English church.

Direction of Dimensions.		Salisbury.	Amiens.
		Feet.	Feet.
Length	from east to west - - - - - -	452	444
—	from the west door to the choir - - -	246	235
—	of the choir - - - - - - -	140	139
—	of the space behind the choir to the Lady Chapel -	65	19
—	of the Lady Chapel - - - - -		48
—	of the transepts from north to south - - -	210	194
Breadth	of the nave - - - - - - -	34½	46
—	of the transept - - - - - -		46
—	of the side aisles - - - - - -	17½	19
—	of the windows - - - - - -	48	44
—	of the nave and side aisles - - - - -	102	84
—	of the west front - - - - - -	115	160
Height	of the vaulting of the nave - - - - -	84	141
—	of the side aisles of the nave - - - - -	38	65
—	of the side aisles of the choir - - - - -		62
—	to the soffit of the grand arches - - -	78	83

316. A more amusing instance of the value of the investigation of architectural subjects by literary men cannot be referred to, than that of Gray the poet having compared the

cathedral of Amiens with that of Canterbury; between which structures there is not the smallest point of resemblance, except in their both being built for religious purposes. The church at Amiens suffered during the Revolution considerably less than any of the other French churches of importance.

317. In closing the view of the pointed architecture of France, it may be useful to add a list of a few of the cathedral churches in that country, with their dates and architects, before the end of the thirteenth century.

Church.	Date.	Architects.
Chartres	1029	Fulber.
Charité sur Loire	1056	Gerard.
Clugny	1070	Hugues.
Notre Dame, Paris	1161	Maurice de Sully. Finished by Jean de Ravy, 1257; and Pierre de Montereau, 1270.
Bec	1212	Ingelramme. Finished by Walter de Meulan, 1216.
Rheims Cathedral	1215	Hugues Libergier. Completed by Robert de Coucy.
Rouen ditto	1216	Ingelramme. Finished by W. de Meulan.
Amiens ditto	1220	Robert de Luzarches.
Sainte Chapelle de Paris	1245	Pierre de Montereau.
Lyons	1270	Robert de Luzarches.
Notre Dame de Mantes	1280	Eudes de Montreuil.
St. Germain des Prés, Paris Chapel of our Lady	1288	Finished. Foundations laid by Pierre de Montereau in 1227.

318. The pointed arch is found throughout Italy. We do not believe there was any great difference in the times of its introduction into the various countries of Europe; the earliest example in Italy is believed to be the church of San Francesco at Assisi. The cathedrals at Orvieto and Sienna, and some beautiful examples at Verona, Vicenza, and Viterbo, show that it prevailed in Italy with many modifications. It is not necessary to pursue its history merely with reference to this country; and we shall therefore content ourselves with a short account of the principal structure in it which exhibits the style. The cathedral at Milan (*fig.* 160.) was begun in 1336, and finished in 1387. It is constructed of white marble. The plan is a Latin cross, the transepts extending but little beyond the walls of the church. From west to east its length is 490 ft., and its extreme breadth 295. Each extremity of the western front has a small square tower 43 ft. wide in each direction. The length of the nave is 279 ft., and its width 197 ft. It is divided longitudinally into a central and four side aisles, and lighted by five cupolas. The transepts are also divided into a central and two side aisles, in the direction of their length. The eastern end of the church is terminated by three sides of an octagon. The architecture of the doors and windows of the western front is of Italian or Roman style, and was executed at a late period; but the whole of it ends upwards in a great gable or pediment, taking in the extreme width of the elevation. Its apex is 170 ft. from the pavement, and the sloping sides are ornamented with tabernacle work. The towers at the angles are 295 ft. high, and are horizontally divided into six stories, which, as they rise, gradually diminish in breadth, the last forming a small pyramidal spire. The faces of the towers are encrusted with tabernacle work, and canopied statues standing on corbels. In the third story from the bottom a painted window, separated into three divisions by mullions, is introduced. The rest of the façade is vertically divided by buttresses into five parts, the buttresses being ornamented with statues on corbels, and terminating in lofty pinnacles. The central tower, which stands over the intersection of the transepts with the nave, rises to the height of 400 ft., being in general form similar to those which appear in the western façade. All the towers and pinnacles are crowned with statues. The roof is covered entirely with

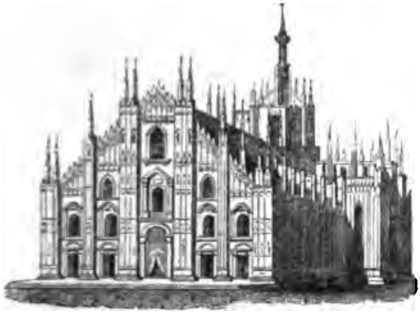


Fig. 160. CATHEDRAL AT MILAN.

blocks of marble, which are fitted together with such exactness that they are like one piece. The principal architect of the fabric was Zamodia, a German. It must be here remarked, that the interior of the cathedral of Milan, which is of the close of the 14th century, is in the same character of style as that which prevailed in France and Germany during the æra. Kerrich (MSS. Brit. Mus.) has very truly said, that "we have nothing which might authorise a strict comparison with the cathedral at Milan, as to the immensity of the work, or the astonishing and endless labour which has been expended upon it. Without ascending the roof, no idea can be formed of the vast profusion of elegantly carved ornaments, the Gothic work, or the astonishing number of statues and alto-rilievos which are found there; some very small, others of a gigantic size—generally speaking good. They possess, of course, different degrees of merit, as having been made in different ages. There is a singular application of them, which is seen I believe no where else—they stand upon the very summit of pinnacles and finials. The *louvre* in the centre of the church is very large, and of grand effect, but is disfigured by a wooden spire. The flying arches are literally feathered with crockets." We subjoin a table, with the dates and architects, of some of the principal cathedrals of Italy, in which the pointed arch is found: —

Place.	Date.	Architect or Founder.
Genoa - - -	1125	Founded by Martino Doria.
Messina - - -	1180	Founded by Ruggiero, Count of Sicily, in 1100.
Palermo, Monte Reale	1185	
Benevento - -	1198	Bishop Ruggiero, nephew of the last.
Padua - - -	1231	Nicola da Pisa.
Arezzo - - -	1240 to 1260	Lapo, a German.
Orvieto - - -	1290	Lorenzo Maitani.
Naples - - -	1260	Giovanni da Pisa.
Sienna - - -	1338	Lapo da Siena.
Milan - - -	1387	Zamodia.

319. In the church of San Lorenzo at Genoa appears a strange mixture of styles: the nave is separated from the aisles by Corinthian columns, connected by pointed arches, and bearing an horizontal entablature, above which reigns an arcade, whose supports are alternately columns and piers. The internal appearance of the church is singular, from the courses of the masonry being alternately of white and black marble. The cathedral at Palermo seems to indicate a Moresque as well as pointed style, and is a curious example, whereof the representations will convey a much better idea than a description here, which, however, we should not decline, if the subject had not already been placed fully before the reader. Every example within the range of Moorish dominion unites to prove the hypothesis on which we have relied.

320. In the splendid cathedrals of Spain a style prevails wherein we find almost an amalgamation of Saracenic with that which prevailed in Europe after the introduction of the pointed arch. That at Seville, which was raised near the end of the 13th century, is 420 ft. long, 273 ft. broad, and 126 ft. high. The choir is in the centre of the church; and the interior, though as respects the plan unintelligibly split into small parts, possesses features of extraordinary beauty. The celebrated *Giralda*, or bell-tower, seated at one angle of it, is perhaps the most picturesquely designed campanile in Europe. The lower part, being 200 of the 300 ft. in height to which it rises, was built by the Moors towards the end of the 10th or beginning of the 11th century. It contains a staircase of so easy ascent that two horsemen may mount abreast more than half way towards its summit. The cathedral at Burgos is another exquisite specimen of the art in Spain, and has always been considered among the best examples of Europe in the pointed style, which on the Continent was always more exuberant in ornament than in this country. It has two towers ending in spires at its west end; and from the central part of the edifice a square tower of great beauty rises, whose sides are ornamented with eight pinnacles. The parts of this cathedral are elaborate, and finished with extraordinary attention to detail. At the eastern end an octagonal building is seated, crowned with a pyramidal roof. This church is said to have been executed on the designs of John and Simon of Cologne, after 1442.

321. Portugal produces a number of examples of the pointed style, one whereof, the church of Batalha (*fig.* 161.), is of the most magnificent description. We always differ with reluctance from Dr. Milner, and especially in the case of the Batalha, which he considers only a pleasing variety of Gothic architecture, and not to be put in competition with many of the contemporary buildings in other parts of Europe on the general principles of sublimity and beauty. Our opinion is directly the reverse. The church at Batalha is 416 ft. in length, and 541 ft. from north to south including the monastery. Its plan is that of a Latin cross, and the

interior is divided by columns into a nave, with an aisle on each side, the eastern end terminating in three sides of an octagon. The aisles are equal in height to the nave; the vaults of both being groined, and springing from clustered pillars. The side walls have two tiers of pointed windows; those of the lower tier having their radii of curvature equal to two thirds of their span, and those above equal to three fourths of it. The windows are splayed towards the interior, their sides being ornamented with a number of small columns, wherefrom stems are produced which meet at the top of the aperture. Each window is in three divisions, separated by upright mullions, and ending in trefoil heads. Six quatrefoils are introduced between the tops of the last and the intrados of the arch. In the chancel the windows are narrow in proportion to their height, and terminate in lancet heads. The main walls are crowned by pierced battlements with pinnacles. The tower is octagonal on the plan, and receives a small open-worked pyramidal spire. Attached to this church, which is constructed entirely of white marble, is the extremely beautiful mausoleum of King John (*fig.* 162.), whose pierced spire reminds one of those in Normandy and Germany, and gives another instance of the universal consent of the age in carrying pointed architecture to the utmost limits of decoration; a desire which, connected with the changes of the times, led to its abandonment very soon after it seems to have reached the acmé of perfection.

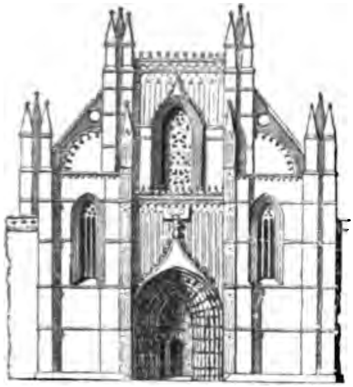


Fig. 161. CHURCH OF BATALHA.

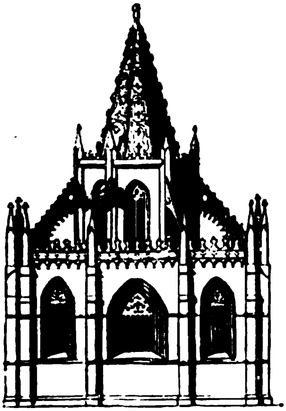


Fig. 162. MAUSOLEUM OF KING JOHN.

322. We here leave the subject of pointed architecture, not without regret, because we are well aware that a much more extended notice than the limits here prescribed is necessary to do justice to it; but that regret is lessened on reflecting that in a subsequent section we shall have to consider it under the head of architecture in the British Isles. The first crusade, it is to be observed, was in 1096, about a century after which the pointed style was approaching perfection on the Continent; the last, or eighth crusade, was in 1270; and it is curious enough to observe that in about a century thereafter the expiring effort in that style appears in the cathedral at Milan. There seems to have been a series of waves of art impinging, like those of the sea on the shores of a continent, on the taste of Europe, and not felt immediately, but in, as it were, the distance of the original wave from its destination; for it is certain that the British Isles were behind the rest of Europe in its adoption. And this we think another satisfactory reason for assigning the origin of the pointed arch to the East.

SECT. XVI.

ITALIAN ARCHITECTURE.

323. The period to which we have advanced in the architecture of Italy is seen in the last section: we have now to commence a new era in the art, which, dawning in Florence, soon spread its meridian light over Italy and the rest of Europe. The French have well applied the term *renaissance* to its commencement. It is with us denominated that of the *revival* of the arts. The Florentines had at an early period, according to Villani, determined to erect in their city a monument which should surpass all that had before appeared; and in 1298 Arnolfo di Lapo, according to Vasari, but according to Molini Arnolfo di Cambio da Colle, to whom they confided its execution, had so prepared his plans that its foundations were in that year laid, on the day of the feast of the Nativity, and the name of Sta. Maria del Fiore was then given to it. This edifice, though com-

menced long before the revival of the arts, seems to have been conceived by its architect in an original style, forming, as it were, a mean between the pointed and ancient style. It is therefore one of particular interest and instruction in the history of architecture, and one wherein we find a construction in which preparation was made for changing the style then prevalent into one sanctioned by the ancient principles of the art; and it is certain that it was the first which gave the hint for the grandest monuments of modern architecture. *Fig.* 163. shows the plan, and *fig.* 164. the half section and half elevation of it. The walls are almost entirely cased with marble. The whole length of it is 454 feet; from the pavement to the summit of the cross is nearly 387 feet; the transept is nearly 334 feet long; the height of the nave 153 feet, and that of the sides aisles 96½. Between the period of the beginning of the edifice and that in which its completion was entrusted to Brunelleschi, many architects of great talent had been employed in carrying on the works: among whom we find the names of Giotto; Taddeo Gaddi; Andrea Orgagna, a man of extraordinary powers, as his Loggia in the Piazza at Florence amply testifies; and Filippo di Lorenzo. The revival of architecture is so connected with the life of Brunelleschi, that a few passages in the latter will assist us in giving information on the former. He was born in 1377, and by his father Lippo Lippi, a notary of Florence, was intended to succeed him in his own profession; but the inclination of the youth bent towards the arts, and the parent with reluctance yielded to it, and placed him with a goldsmith, an occupation then so connected with sculpture that the greatest artists of the time applied themselves to the chasing and casting ornaments in the precious metals. Brunelleschi, though skilful as a sculptor, had many rivals; and ambitious, it would seem, to be the first in the art to which he should apply his powers, determined to devote himself entirely to architecture, in which the field was then unoccupied. In company with Donatello he therefore visited Rome, and applied himself with ardour to the study of the ruins in the Eternal City; and what was said by Constantius on seeing the forum of Trajan, as related by Ammianus Marcellinus, might be truly said of Brunelleschi: —"Hærebat attonitus per giganteos contextus circumferens mentem, nec relatu affabiles, nec rursus mortalibus appetendos." It was in Rome, though he never communicated his thoughts on the subject to his friend Donatello, that he began to meditate upon the scheme of uniting by a grand cupola the four naves of the Duomo at Florence; a project which till his time was considered almost impossible. During his residence, also, he traced and settled in his mind the proportions of the orders of architecture from the classic examples which the city afforded. Here it was that he studied the science of construction as practised by the ancients: from them he learnt that perfect accordance which always exists between what is useful and what is beautiful, both of which are reciprocally subordinate to each other. Here he discovered the principles of that nice equilibrium, equally requisite for the beauty no less than for the solidity of an edifice. In short, throughout he found "sermons in stones;" and, having thus qualified himself for the great work he sought, returned to Florence in 1407. In this year the citizens convoked an assembly of architects and engineers to deliberate upon some plan for finishing the Duomo, as Sta. M. del Fiore is usually called; a name given to the cathedrals of the cities of Italy. To this assembly Brunelleschi was invited, and gave his advice for raising the base drum or attic story upon which the cupola should be placed. It is not important here to detail the jealousies of rivals which impeded his project; nor, when the

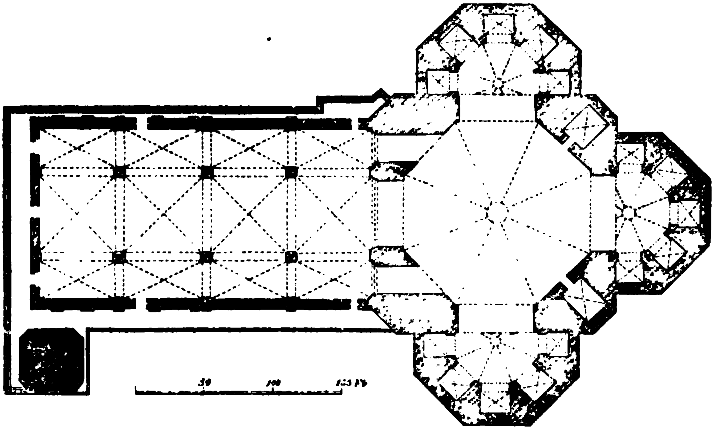


Fig. 163. PLAN OF SANTA MARIA DEL FIORE AT FLORENCE.

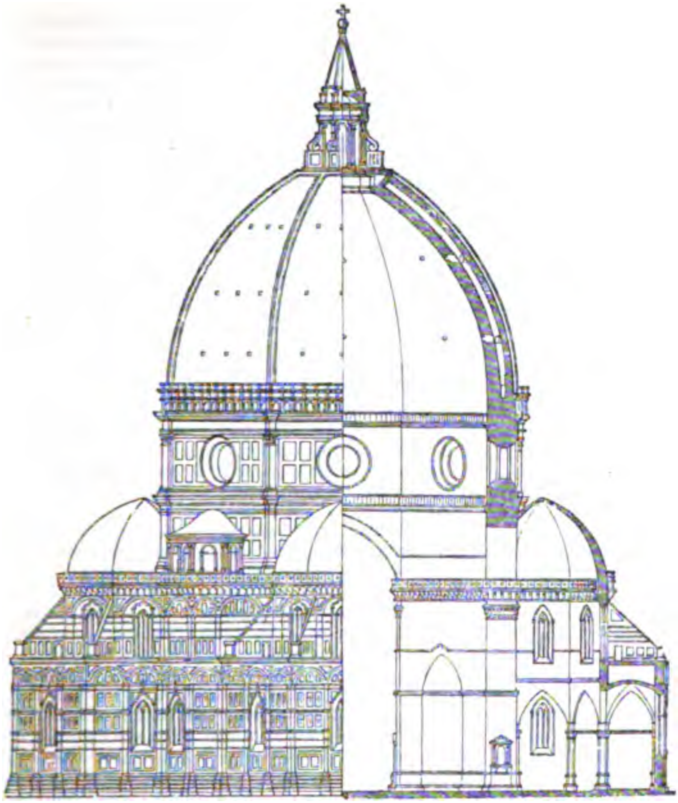


Fig. 164. HALF ELEVATION AND HALF SECTION OF SANTA MARIA DEL FIORE.

commission was at length confided to him, the disgraceful assignment to him of Lorenzo Ghiberti as a colleague, whose incapacity for such a task our architect soon made manifest. Suffice it to say, that before his death he had the satisfaction to see the cupola finished, with the exception of the exterior of the drum under the cupola; for whose decoration, as well as for the lantern with which he proposed to crown the edifice, he left designs, which, however, were lost. One of the directions he left on his death particularly insisted upon the necessity of following the model he had prepared for the lantern, and that it was essential that it should be constructed of large blocks of marble so as to prevent the cupola from opening; an advice which experience has since proved in other cases to be far from sound. This cupola is octagonal on the plan, as will be seen by reference to the figures, and is 138 feet 6 inches in diameter, and from the cornice of the drum to the eye of the dome of the height of 133 feet 3 inches. Before it nothing had appeared with which it could be fairly put in comparison. The domes of St. Mark and that at Pisa are far below it in grandeur and simplicity of construction. In size it only yields to St. Peter's at Rome, for which it is probable it served as a model to Michael Angelo; for in both, the inner and outer cupolas are connected in one arch at their springing. It is moreover well known that Buonarroti's admiration of it was so great that he used to say that to imitate it was indeed difficult, to surpass it impossible. Vasari's testimony of it shall close our account of this magnificent structure: — "Se puo dir certo che gli antichi, non andarono mai tanto alto con lor fabriche, ne si messono a un risico tanto grande, che eglino volessino combattere col cielo, come par veramente ch' ella combatta, veggendosi ella estollere in tant' altezza che i monti intorno a Fiorenza paiono simili a lei. E nel vero pare, che il cielo ne abbia invidia poiche di continuo le saette tutto il giorno la percuotono." It might be supposed that such a work was sufficient to occupy the whole of Brunelleschi's time; not so: the Duke Filippo Maria engaged him on the fortifications at Milan, besides which he was employed on several other military works; a proof of the great diversity of talent he possessed. It is, therefore, from the extensive employ he enjoyed, not only in Florence, but in many other parts of Italy, quite certain that he infused a new taste into its buildings, and that he is justly entitled to the title of the Restorer of Architecture in Europe. He died, and was buried in the church he had raised in 1444. He left a number of scholars, among whom Luca Fancelli and Michelozzo were perhaps the ablest. These pupils spread throughout Italy the effects of the vast change that had been thus begun; a taste for architecture was excited; its true principles became known; and in a short space of time, as if the matter had been one of arrangement between them, the illustrious house of Medici, the dukes of Milan, and the princes and nobility of the country contended who should most patronise its professors. The learned began to expound to artists the books of Vitruvius, the only writer among the ancients whose works on that subject have come down to us.

324. Leo Battista Alberti, of the ancient and illustrious family of the Alberti of Florence, succeeded Brunelleschi in carrying on the great change of which we have been speaking, and was, indeed, a great contributor to the art, not only by his literary labours on architecture, in which he displays profound erudition, knowledge of construction, and an intimate acquaintance with the works of the ancients, but also by the distribution, elegance, grace, and variety, which his designs exhibit. His book, *De Re Edificatoriâ*, is the foundation of all that has been since written on the art, and deserves careful perusal by every one who studies for the purpose of practice. We shall here present a short account of it, which, in imitation of Vitruvius, he divided into ten books.

325. The *first* book treats on the origin and utility of architecture; the choice of the soil and situation for placing buildings; the preparation, measurement, and suitable division according to their nature, of the edifices to be erected; of columns and pilasters; of the different kinds of roofs, doors, and windows, their number and size; of the different sorts of staircases and their landings; of the sewage or drains, and of suitable situations for them respectively. In the *second* book the subjects are, the choice of materials; the precautions to be taken before beginning a building; the models, of whatever description, that should be made; the choice of workmen; the trees fit for use, and the season in which they should be felled; the methods for preventing rot, and susceptibility of fire; of stone in its varieties; the different sorts of bricks, tiles, lime, sand, and mortar. The *third* book treats of construction; foundations according to the varieties of soil; encroachments; the carrying up and bond of masonry; rough and rubble work; on the different sorts of masonry; on the inlaying and facing of walls; on beams, joists, and the method of strengthening them; on floors, arches, and vaults; the covering of roofs, pavements, and the season for beginning and completing certain works. The *fourth* book is confined to the philosophy of the art, showing the causes which influence mankind in the adoption of modes of building according to the climate, the soil, and the habits or government of a people. It, however, treats of the proper position of a city; of the size to be given to it; of the form of the walls; of the customs and ceremonies of the ancients as applied to this point; of fortifications, bastions or towers, gates and ramparts; bridges, both of timber and stone; sewers, ports, harbours, and squares requisite in a city. The *fifth* book contains instructions for the erection of palaces for peaceable, and castles for absolute princes; for the houses required by a republic; large and small religious edifices; academies, public schools, hospitals, and palaces for senators. In it are given some hints on military and naval architecture, on farm buildings, and country houses. In the *sixth* book Alberti treats on architectural ornament, columns, and the method of adjusting their proportions. After some observations on the principles of beauty, on taste, and on the mode of improving it, he enters shortly on the history of architecture. These are followed by several chapters on the doctrine of mechanics, machines, the method of raising and working columns, polishing them, imitations in stucco and incrustation in thin layers, and matters of that nature. The *seventh* book continues the discussion on ornaments in architecture, but chiefly in respect of columns, showing the edifices in which the use of them is suitable; and, in imitation of Vitruvius in his directions relative to temples, our author dilates on buildings for ecclesiastical purposes. He shows what sorts of columns and pilasters are best suited to them, how far the employment of statues is proper, and how they should be sculptured. The *eighth* book is on roads and their decorations, tombs, pyramids, columns, altars, epitaphs, &c. In it he turns to the subjects of streets, cities, ornaments appropriate to gates, ports, arches, bridges, crossways, markets, public squares, walks, porticoes, theatres, amphitheatres, circi, libraries, colleges, baths, &c.; and the style in which public buildings should be constructed and decorated. The *ninth* book is a continuation of the preceding one; but in this he speaks in addition of the appropriate decoration of royal palaces, and of the ornaments respectively suitable to city and country dwellings, and of the paintings and sculpture that should be employed in them. In the *tenth* and last book the principal subject is the finding a supply of water for buildings both in town and country, and it closes with some useful hints on the aid of architecture to domestic economy. This truly great man constructed many works in different cities of Italy, some of which still remain to

attest his skill. We are not to examine them with the eye of an architect flourishing even half a century later, though under that category they do him honour, but with the eye of an artist of his own day, and we shall then find our veneration for his memory cannot be too strongly expressed. In Florence he finished the Pitti palace, and built the choir of the Annunziata. At Mantua he built a church of singular beauty, consisting of a simple nave, crowned with a vault decorated with *caissons*, which rivals the works of the ancients. The additions he made to the church of St. Francesco at Rimini, a pointed church, though not in the same style, because it then came into disrepute, show an extraordinary aptitude for overcoming the most difficult and repulsive subjects with which an architect has to deal, and that work alone would stamp him as a man of genius. On his other acquirements it is not within our province to dwell; we shall merely sum them up by saying that he was poet, painter, sculptor, philosopher, mathematician, and antiquary. Such was Alberti, in whom was concentrated more refinement and learning than have hardly since appeared in a single individual of our species. The time of his death is not accurately known; some place it at the end of the fifteenth, and others at the beginning of the sixteenth century.

326. About the time that Alberti was engaged on the practice and literature of the art, a very extraordinary volume, written by a member of the Colonna family, was published by Aldus, at Venice, in 1499, folio. Its title is as follows: — *Polyphili Hypnerotomachia; opus italicâ linguâ conscriptum; ubi humana omnia non nisi somnium esse docet.* This work deserves to be better known than we fear its rarity will ever permit. With the singularity of the plan, it unites the advantage of placing before the reader many elevated and elegant ideas, and, under the veil of a fable, of inculcating precepts of the greatest utility to artists and those that love the art. The testimony of Felibien in favour of this work runs so favourably, that we must transcribe it:—" Sans préjudice," says that author, " du grand profit qu'on peut tirer de la lecture de Vitruve, et de l'étude qu'on doit faire de ses principes et de ses règles, il ne faut pas moins examiner les tableaux curieux de plusieurs superbes édifices, monumens ou jardins, que l'imagination riante et féconde de l'auteur du *Songe* a mis sous les yeux de ses lecteurs." When it is recollected that the manuscripts of Vitruvius were extremely rare, and that when Colonna wrote (1467) that author had not been translated, — when we reflect that in his descriptions he rears edifices as magnificent and regular as those which Vitruvius presents to us, we cannot withhold our surprise at the genius and penetration of the author. With him architecture appears in all her majesty. Pyramids, obelisks, mausolea, colossal statues, circi, hippodromi, amphitheatres, temples, aqueducts, baths, fountains, noble palaces, delicious gardens, all in the purest taste and of the most perfect proportion, attend in her train, and administer to the pomp with which the author attires her. With him all these ideal productions of the art were not merely the result of an ardent imagination, but were the fruit of an intimate acquaintance with its rules, which he explains to his reader, and inspires him at the same time with a taste for the subject of his pages. He often breaks out against the gross ignorance of the architects of his day, and endeavours to inculcate in them the sound principles of the art. He demonstrates that it is not enough that an edifice possesses stability and solidity, but that it must be impressed with a character suitable to the purpose for which it is destined; that it is not enough that it be well decorated, but that the ornaments used arise from necessity, or at the least from utility. Architecture thus treated in fiction was much more pleasantly studied than it would have been by mere application to the dry rules of Vitruvius. The impression made by the work was increased by the poetic glow with which the precepts were delivered; the allegories it contained warmed the imaginations of a people easily excited, and Italy soon saw realised what Polyphilus had seen in a dream. This work is decorated with wood engravings of singular beauty, in which the details and accessories are strictly classical; it is written with great spirit and elegance, and we are not amazed at the magical effect which, with the accompaniment of Alberti's book above mentioned, it every where produced.

327. The Italian school, which ultimately appropriated and adapted the ancient Roman orders and their details to comparatively modern habits, was for a long while engrafted on or amalgamated with what is called Gothic. We here (*fig.* 165.) place before the reader an instance of this, in the celebrated Loggia at Florence, designed by Orgagna. The same feeling appears, indeed, in what Brunelleschi did in his Duomo, and in many other buildings in Florence, in Pisa, Sienna, and other cities. Brunelleschi doubtless made a strong effort to emancipate himself altogether from the mixture of two discordant styles, and in some measure succeeded. Still there continued, as is evident in the Ricardi, Strozzi, and other palaces in Florence, a lingering love for the mixture, which the architects had great apparent difficulty in shaking off. It is, however, extraordinary that with all this lingering love for the ancient style, in which there was much littleness, when the architects of this period came to the crowning members of their edifices, they placed on them such massive and finely composed cornices that the other parts are quite lost; and in this member it is evident they were influenced by those feelings of unity and breadth that gave so much value to the best works of the ancients.

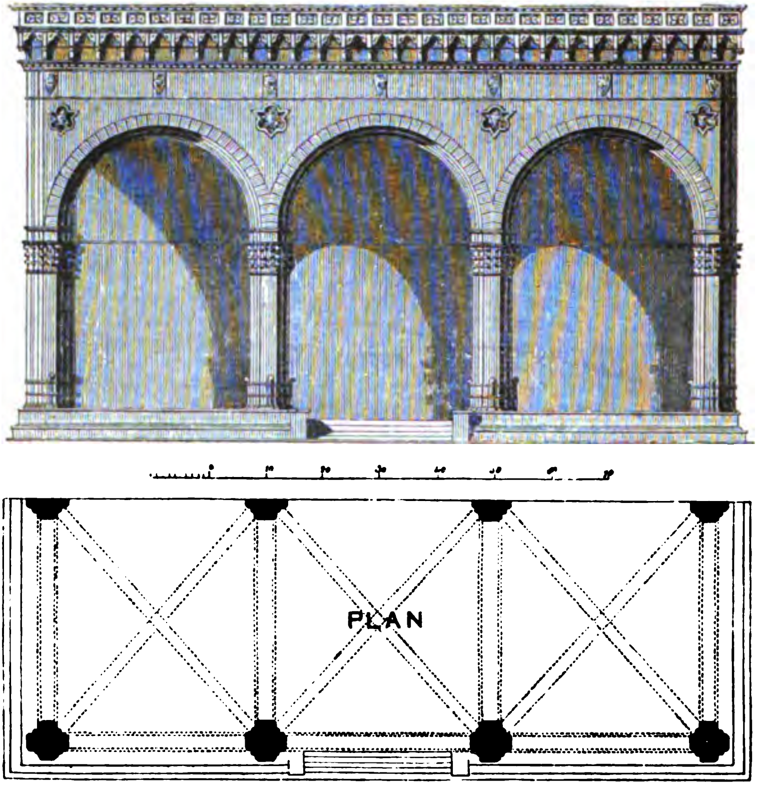


Fig. 165. LOGGIA OF ORCAGNA.

328. The revival of the arts in Italy was vastly assisted by the commerce and riches of the country; and with the decay of that commerce, nearly 300 years afterwards, their palmy days were no more: from that time they have never thriven in the country that gave them birth. It is our intention, in this view of Italian architecture, to consider it under the three schools which reigned in Italy — 1. The Florentine; 2. The Roman; 3. The Venetian.

329. 1. *Florentine School.* — Climate and the habits of a people are the principal agents in creating real style in architecture; but these are in a great measure controlled, or it is perhaps more correct to say modified, by the materials which a country supplies. Often, indeed, these latter restrict the architect, and influence the lightness or massiveness of the style he adopts. The quarries of Tuscany furnish very large blocks of stone, lying so close to the surface that they are without other difficulty than that of carriage obtained, and removed to the spots where they are wanted. This is probably a circumstance which will account for the solidity, monotony, and solemnity which are such commanding features in the Florentine school; and which, if we may judge from the colossal ruins still existing, similarly prevailed in the buildings of ancient Etruria. In later times another cause contributed to the continuation of the practice, and that was the necessity of affording places of defence for the upper ranks of society in a state where insurrection continually occurred. Thus the palaces of the Medici, of the Pitti, of the Strozzi, and of other families, served almost equally for fortresses as for palaces. The style seems to have interdicted the use of columns in the façades, and on this account the stupendous cornices that were used seem actually necessary for the purpose of imparting grandeur to the composition. In the best and most celebrated examples of their palaces, such as the Strozzi, Pandolfini, and others in Florence, and the Picolomini palace at Sienna, the cornices are proportioned to the whole height of the building considered as an order, notwithstanding the horizontal subdivisions and small interposed cornices that are practised between the base and the crowning member. The

courts of these palaces are usually surrounded by columns or arcades, and their interior is scarcely ever indicated by the external distribution. From among the extraordinary palaces with which Florence abounds, we place before the reader the exquisite façade of the Pandolfini palace, the design whereof (*fig.* 166.) is attributed to the divine Raffaelle d'Urbino.

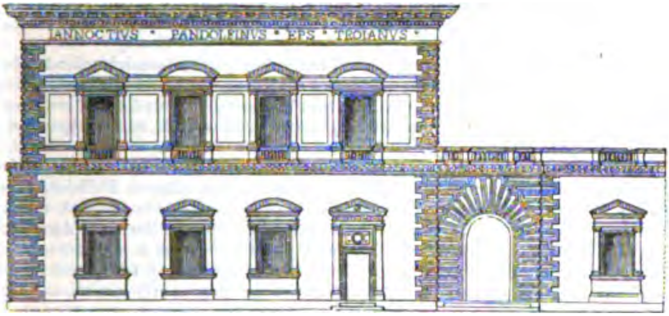


Fig. 166. PANDOLFINI PALACE.

In it almost all the requisites of street architecture are displayed. It is an example wherein the principles of that style are so admirably developed, as to induce us to recommend it, in conjunction with the façade of the Farnese palace hereafter given, to the elaborate study of the young architect.

330. Without further allusion to the double cupola of the Duomo, already noticed, the first of its species, and the prototype of that of St. Peter's at Rome afterwards reared by Michael Angelo, the principles and character of the Florentine school are not so manifest as in its palaces. These nevertheless possess great interest; for they were the bases on which those of the Roman school were formed, as well as of those examples which, with different degrees of purity, were afterwards erected in many of the capitals of Europe. Besides the plan of the Duomo, those of St. Michele, Sta. Maddelina, St. Pancrazio, St. Lorenzo, and St. Spirito, are the key to all excellence in modern art, as respects real church architecture. It is unfortunate that of this school few of the churches have been finished, so that their façades are generally imperfect. The interior was properly, with them, a matter to be first considered and brought to perfection.

331. Amongst the many extraordinary architects of the Florentine school, whereof a list will hereafter be given, was Bartolomeo Ammanati, whose bridge, "*della Santissima Trinità*," sufficiently proves that the greatness of the Florentine school does not alone depend on its palaces and churches. This, one of the most beautiful examples, as well for design as constructive science, in which was obtained for the waters of the Arno a maximum of waterway, combined with a beauty of form inappreciable through graphic means, still strides the river of Florence, to attest the consummate skill of Ammanati. The bridge in question consists of three arches: the middle one is 96 ft. span, and each of the others 86 ft.; the width of the piers is 26 ft. 9 in., and the breadth of the bridge between the parapets is 33 ft. The arches are very slightly pointed, the cusp being hidden by the rams' heads sculptured on the keystones; their rise above the springing is very little, hence they have been mistaken by some writers for cycloidal arches. Alfonso and Giulio Parigi, who assisted in constructing the work, left an account of the mode in which it was carried on, and the manuscript is still preserved in the Florentine Library. More recently, a description of this bridge has been published by Ferroni, under the title of "Della vera Curva degli Archi del Ponte della Santissima Trinità di Firenze." The Pitti palace had been begun in the time of Brunelleschi, in 1435, for Luca Pitti, a wealthy citizen of Florence. Remaining long unfinished, it was at last sold to Eleonora, wife of Cosmo I., who purchased the adjoining ground, and planted the Boboli Gardens. About the middle of the 16th century, Nicolo Bracciani, surnamed Tribolo, made designs for finishing the building; and was succeeded by Bernardo Buontalenti. After him came our Ammanati, who left other designs for finishing, which was accomplished by Alfonso and Giulio Parigi. It is now the residence of the grand duke, and has served as a model for imitation to many modern architects, though there is in it much to condemn. The details, however, and proportions of the orders used in it by Ammanati, are very beautiful. This architect died in 1586, at the age of seventy-five. He was a pupil of Baccio Bandinelli, and during his life composed a large work, entitled *La Città*, which contained designs for all the fabrics belonging to a regular and well-arranged city, beginning with the gates, then proceeding to the palaces of the prince and magistrates, the churches, the fountains, the squares, the loggia for the

merchants, the bridges, theatres, &c. This work appears to have been lost, the last possessor of it known having been the prince Ferdinand of Tuscany. Though in the higher refinement of finished details the Florentine school did not reach the extreme elegance of the Roman and Venetian schools, yet for bold imposing masses of architecture we think no city presents such a collection of highly picturesque architectural examples as Florence. The Pitti palace indeed, just mentioned, is more imposing by its broad parts than almost any other building with which we are acquainted, though it becomes poor when translated into French, as at the Luxembourg.

332. So late as 1454, we find in the Strozzi and other palaces semicircular-headed windows, wherein are half columns at the sides, and a column in the middle, resembling those in the Byzantine or Romanesque edifices. The two apertures thus formed are crowned by semicircular heads, which are circumscribed by the outer semicircle, and the spandrel formed by the three curves is occupied by a patera.

333. The period of the Florentine school, which must be taken as commencing with Brunelleschi, includes the names of Michelozzo, Leo Battista Alberti, Pollaiuolo (who obtained the soubriquet of Chronaca, from his constant recital of his travels), the architect of the Strozzi palace, Raffaelle Sanzio, Benedetto da Majano, Baccio d'Agnolo, Baccio Bandinelli, Buontalenti, Ammanati, and others: it extends from A. D. 1400 to A. D. 1600. The works of Michael Angelo, though a Florentine, do not belong to this school; neither do those of San Gallo and some others, who have been improperly classed as Florentine architects.

334. 2. *Roman School.*—Though the city of Rome, during the period of the rise and progress of the Roman school of architecture, was not altogether free from insurrectionary troubles, its palatial style is far less massive than that of Florence. None of its buildings present the fortress-like appearance of those in the last-named city. Indeed, the Roman palaces, from their grace and lightness, indicate, on the part of the people, habits of a much more pacific nature, and an advancing state of the art, arising from a more intimate acquaintance with the models of antiquity which were on every side. The introduction of columns becomes a favourite and pleasing feature, and great care and study appear to have been constantly bestowed on the façades of their buildings; so much so, indeed, in many, that they are but masks to indifferent interiors. In them the entrance becomes a principal object; and though in a great number of cases the abuses which enter into its composition are manifold, yet the general effect is usually successful. The courts in these palaces are most frequently surrounded with arcades, whence a staircase of considerable dimensions leads to the sala or principal room of the palace. The general character is that of grandeur, but devoid altogether of the severity which so strongly marks the Florentine school. The noblest example of a palace in the world is that of the Farnese family at Rome, to which we shall afterwards have occasion to return.

335. Bramante, born in 1444 at some place, but which is still in doubt, in the duchy of Urbino, must be considered the founder of the Roman school. Though educated as a painter under Fra Bartolomeo, and likely to have ranked in that occupation as a master of no ordinary powers, his great love of architecture induced him at an early period to quit painting as a profession. In Lombardy he wandered from city to city for the purpose of obtaining employment as an architect, but there is no evidence that his exertions in that part of Italy were rewarded with great success. The dry style which afterwards characterised his works has been said to have had its origin in his protracted stay at Milan, while the works of the Duomo were carrying on there under Bernardino di Trevi, a builder of such skill as to have gained the esteem of Leonardo da Vinci. Be this as it may, it was in this city his determination to follow our art became irrevocable. From Milan he went straightway to Rome; where, however, he was obliged to make himself known by some works in his first profession of a painter in the church of St. Giovanni Laterano. Naturally of hospitable and social disposition, and a lover of expense and luxury, so intense was his ardour to become great in the art he adopted that he refrained from all society, holding commerce only with the monuments of antiquity by which he was surrounded, studying with the utmost diligence, and drawing them for his future application of the principles upon which they were founded. He even extended his researches to Naples, losing no opportunity of noting all the ruins from which instruction in his art could be drawn. Oraffa (Cardinal of Naples), who had remarked his zeal, gave him his first commission in Rome, which was the construction of the cloister of the Convent della Pace; and this, from the intelligence and speed with which he executed the task, brought him at once into repute. At this period Rome could boast but of few architects, and those that were established there were of small account. The Florentine school seems to have sprung in the most decided manner from the habits of the people and the massiveness of their materials, modified by some knowledge of the buildings of the ancients; that of Rome seems to have been founded upon the principle of making the ancient architecture of Rome suit the more modern habits of a very different people, though living on the same spot. To explain more immediately our meaning, we cite the small circular chapel

of St. Pietro in Montorio, wherein we find a jump at once in the adaptation of the circular peripteral temple of the Romans to the purpose of Christian ceremonies. And again, it is impossible to look at the Palazzo della Cancelleria without being struck by the basement and two orders, which would be suggested by a contemplation of the Coliseum, though afterwards the Roman architects had the good sense to see that the orders of architecture placed against the walls of a building where the use was not required by the interior distribution was a tasteless and useless application of them. The architect of the Palazzo Farnese only uses them for the decorations of his windows. In this respect we hope good sense is once more returning to this country; and that the absurd practice in almost every case of calling in the orders to aid the effect of a façade, will be abandoned for the better plan of obtaining an imposing effect from the simplicity and arrangement of the necessary parts. We must, however, return to Bramante, whose other employment we pass over to come to his great work,—one which, after the continued labour upon it of his successor Michael Angelo, seems to have exhibited the great canons of art; one which has regulated all the modern cathedrals of Europe, for they are, in fact, but repetitions of it; and one, therefore, which requires a lengthened notice in this place, as intimately connected with the rapid progress of the Roman school. The ancient Basilica of St. Peter had become so ruinous that Pope Nicholas V., a man who delighted in magnificent undertakings, a lover of architecture, and of more than ordinary genius, had conceived the project of rebuilding it, and under the designs of Bernardo Rosellini had actually seen a portion of the design rise from the ground before his death. The project seemed then to be forgotten and abandoned, until Michael Angelo Buonarroti, seeking a place for the erection of the mausoleum of Julius II., upon which he was engaged, thought that the tribune of Rosellini's projected new basilica would be well suited for its reception, and accordingly proposed it to the pontiff. Julius, pleased with the suggestion, immediately sent for San Gallo and Bramante to examine into it. In these cases, one project generally suggests another, and the rearing a new St. Peter's became a fixed object in the mind of Julius II. The tribune of Nicholas V. was no longer thought of, except as a space to be included within the new works. He consulted several architects upon the subject; but the fact is, that the only real competition lay between Giuliano di San Gallo and Bramante. The last was the successful artist; and from a great number of projects the pope at last chose that upon which St. Peter's was afterwards commenced. The real design of Bramante can scarcely be traced in the basilica of the Vatican as executed. The changes it was doomed to undergo before completion, more than perhaps any other building was ever subjected to, have been drawn into a history by the Jesuit Bonanni. When Bramante died, his designs, if indeed he made any, were dispersed; and for what we do know of them we are indebted to Raffaelle, who took much pains in collecting the ideas of our architect, as they afterwards appeared in Serlio's Treatise on Architecture. The original plan of Bramante was simple, grand, and in its parts harmonious, and would doubtless have been effective, far beyond the edifice as executed. It has been well observed by Q. de Quincy, in his Life of Bramante, "Le Saint Pierre d'aujourd'hui parait moins grand qu'il ne l'est en effet. Le Saint Pierre de Bramante aurait certainement été plus grand encore en apparence qu'en réalité." There would moreover have been an accordance between the interior and exterior. The peristyle was to have three ranks of columns in depth, which would have necessarily had unequal intercolumniations. The cupola was rather that of the Pantheon, ornamented exteriorly with an order of columns. Bramante carried his imitation even to the steps round the springing of that monument. From the medals of the design struck about the period, it seems that the façade was to have been decorated at its extremities with two campanili; but the authority of a medal may be doubtful. The idea, therefore, which is said to have originated with Michael Angelo, of placing the dome of the Pantheon upon the vaulting of the Temple of Peace emanated from Bramante, though the honour of actually carrying such a project into execution belongs to Michael Angelo da Buonarroti. It is not, however, probable that if Bramante had lived he could have strictly executed the design he produced; for it has been well proved that the piers which carry the dome would not have been sufficiently substantial for the weight to be placed upon them, inasmuch as Bramante's cupola would have been much heavier than that executed by Michael Angelo, and that architect considered it necessary to make his piers three times as thick as the former had proposed for his cupola. Bramante's general design having been adopted by Julius II., was immediately commenced with a boldness and promptitude of which few but such men as Julius and Bramante were capable. One half of the ancient basilica was taken down; and on the 18th of April, 1506, the first stone of the new fabric was laid by the pope in the pier of the dome, commonly called that of Sta. Veronica. The four piers soon rose; the centres were prepared for connecting them by vaults, which were actually turned. The weight and thrust of the vaults, however, bent the piers, and cracks and fissures made their appearance in every direction. Thus, without more than their own weight, much less that of the cupola, the works threatened ruin. The great haste used in carrying on the works had doubtless much contributed to this catastrophe. Bramante in the meantime dying, Raffaelle, Giocondo, and Giuliano di San Gallo, and afterwards Baldazzare Peruzzi and Antonio San Gallo, were engaged on the edifice, and severally used the proper means for remedying the defects that had arisen, and for fortifying the great piers of the dome. To do this, as well as to push forward its completion, Michael Angelo was employed; and the rest of that great man's life was chiefly devoted to carrying on, under his own designs, the works of the fabric. From the death of Bramante in 1513 to 1546, when Antonio San Gallo died, the architects above named, all of whose names are almost sacred, had been more or less employed upon it. It was during this period that Bramante's original plan of a Latin was changed into a Roman cross by Peruzzi. The works had at this time become the source of much jobbing; every body that had any employment on them seemed bent on providing for himself, when Michael Angelo consented, for he was far from desirous of being employed, to superintend the future progress of the fabric. The first use made of his authority by Michael Angelo was that of discharging all the agents and *employés* of the place; he may be said to have again driven the money-lenders out of the temple. That he might have more moral power over this worthless race, he set the example of declining to receive the salary of 600 crowns attached to his appointment as architect, and gratuitously superintended the works during the period of seventeen years,—a disinterestedness that afterwards found a parallel in one of the greatest architects that this or any other country ever saw: we needly scarcely mention the name of Inigo Jones. Michael Angelo began by undoing what his predecessor San Gallo had executed; and after having accomplished that, his whole powers were directed towards carrying on the structure to such a point that no change could possibly be made in his plans; so that after having strengthened the great piers, vaulted the naves, and carried up the exterior pedestal of the cupola, at the death of Paul III. in 1549 the form of these parts of the basilica was unchangeably fixed. Under Julius III., the successor of Paul, the intrigues which had always been carried on against Michael Angelo were renewed. He was accused of having contrived the arrangement without sufficient light, and of having changed every thing his predecessors had done. Thus proceeded this great work; but notwithstanding the severe trials he had to undergo from the envy of his contemporaries,—rivals he could not encounter,—Buonarroti steadily pursued his course. He felt that his own destiny and that of the fabric were identical; and, notwithstanding all the disgusting treatment to which he was exposed, determined to stand to his post while life remained. Writing to Vasari, he says, "For me to leave this place would be the cause of ruin to the church of St. Peter, which would be a lamentable occurrence, and a greater sin. As I hope to establish it beyond the possibility of changing the design, I could first wish to accomplish that end; if I do not already commit a crime, by disappointing the many cormorants who are in daily expectation of getting rid of me." And in another letter to Messer Lionardo Buonarrotti, in reply to the pressing instance of the grand duke to have him at Florence, he says, "I would prefer death to being in disgrace with the duke. In all my affairs I have endeavoured to adhere to the truth; and if I have delayed coming to Florence as I promised, the promise should have been construed with this condition, that I would not depart hence until the fabric of St. Peter's was so far advanced as to prevent its being spoiled by others, and my design altered; nor to leave opportunity for those thieves to return and plunder, as has been their custom, and as is still their hope. Thus placed by Divine Providence, I have exerted myself to prevent those evils. As yet, however, I have not been able to succeed in advancing the building to that point which I desire, from want of money and men; and being old, without any one about me to whose care I could leave the work, as I serve for the love of God, in whom is all my hope, I cannot abandon it." At this period, with the letter, to which we have not done sufficient justice in the translation, it is impossible not to sympathise, nor to be unaffected by the simple and unbending honesty of this honour to the race of man, independent of all our admiration of his stupendous power as an artist. At the age of eighty-seven, the pedestal being then ready for the reception of the cupola, he made a small model in clay for that important feature of his work, which was afterwards, to a scale, accurately under his direction, executed in wood; but deficiency in the funds prevented the progress of the building. To the height of upwards of 28 ft. above the exterior attic the cupola is in one solid vault, whose diameter is near 139 ft. at its springing, at which place its thickness is near 10 ft. exclusive of the ribs. As the inner and outer vaults are not concentric, the interval between them increases as they rise. Where they receive the lantern they are 10 ft. 7 in. apart. The construction of this dome proves the profundity of the architect's knowledge as a scientific builder to have equalled his superiority as an architect.

336. After the death of Michael Angelo, this cupola with its lantern was rigorously executed, upon the model he had left, by Jacopo della Porta and Domenico Fontana. His intentions were religiously respected, in the completion of the fabric, until the time of Pirro Ligorio, whom Pius IV. deprived of his situation for attempting to swerve from the model and substitute his own work.

337. Between the foundation of the church by Bramante, and its entire completion by

Carlo Maderno, as seen in *figs.* 167. and 168., a century had elapsed, but during that century

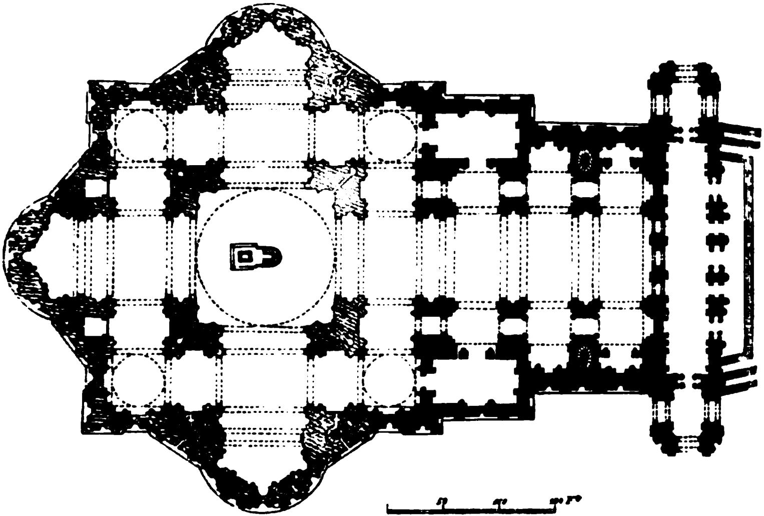


Fig. 167. PLAN OF ST. PETER'S.

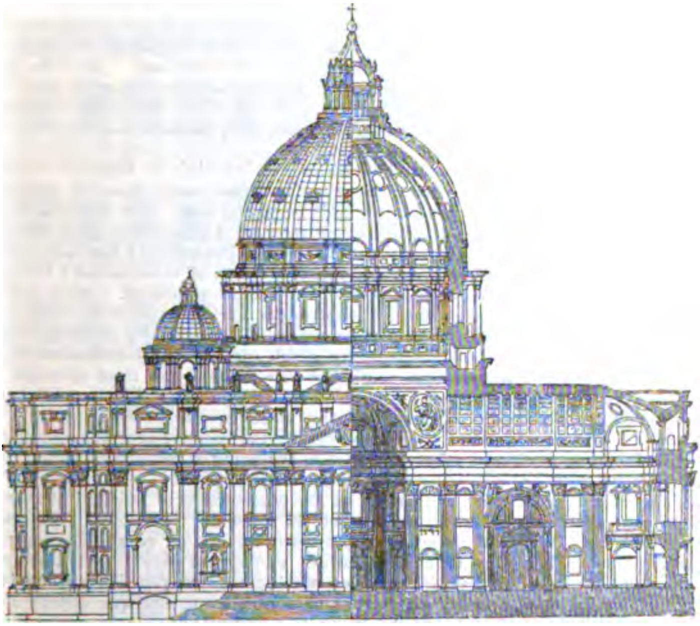


Fig. 168. HALF ELEVATION AND HALF SECTION OF ST. PETER'S.

architectural as well as graphical and plastic taste had undergone great changes; and though the first was still far from the vicious point to which Borromini carried it, the great principles of order and authority, as founded on the models of antiquity, were passed away, and no longer occupied the attention of the architect. The spirit of innovation, too often mistaken for genius, had made such inroads, that regularity of plan, simplicity of form, and the happy union of taste with common sense had altogether disappeared. The part added to the edifice by Maderno appears in the plan with darker lines, by which it is seen that he added three arcades to the nave, in which the same ordonnance is continued.

338. Respecting the alteration in, or rather addition to the plan, it is, and is likely to continue, a moot point, whether this change by Maderno has injured the effect of the church. "There are," says De Quincy, "in the method of judging of works of architecture, so many different points of view from which they may be judged, that it is quite possible to approve of even contrary things." We are not ourselves disposed to censure the application of Maderno, though it cannot be denied that the symmetry of the fabric was in some measure destroyed by it. It is possible that the constant habit of seeing cathedrals with a prolonged nave, before we first saw St. Peter's, may have disposed us to look leniently at a point which so many better judges than ourselves have condemned. Michael Angelo's plan was, doubtless, one of great simplicity and unity. According to his intention, the cupola was the principal feature, the four arms of his cross being accessaries which would not interfere with or lessen the effect of its grandeur, whose points of view could not be much varied. On the other hand, the edifice, enlarged according to the first project of Bramante, has acquired an immensity of volume, which, observes the author before quoted, one would be now sorry to see it deprived of. "*Ce sont deux grandeurs voisines sans être rivales.*" In its exterior, however, it must be admitted that the prolongation of the nave has not improved the effect; and that arose from the necessity of strictly conforming to the forms that existed. It is manifest that the number of divisions which resulted from the mixtilinear plan of Michael Angelo would not well sort with the extended mass which the nave created. It was absolutely necessary that it should be conformable with what had been completed; and the effect of this was lessening the elevation of the cupola in an almost fatal manner. The façade of entrance cannot in any way be defended; and it is much to be regretted that the fine entrance designed by the great master was lost to the world. .

339. St. Paul's is, perhaps, the only great instance in Europe wherein the design was made and wholly carried into execution by the same architect. Works of this nature usually exceed the space of man's life. St. Peter's was altogether a century and a half in building. The change of architects is not the least inconvenience of such a state of things; for during so long a period such a change of taste arises that the fashion and style of an art are from accident scarcely the same at its commencement and end. Thus the church of the Vatican, which was begun by Bramante in a comparatively pure style, was, in the end, defaced by the vicious bizarres of Borromini. It was fortunate Michael Angelo, so far foreseeing accidents of this nature, had fixed unchangeably the main features of his composition.

340. That the first idea of this stupendous fabric owes its origin to Bramante cannot be disputed; but its greatness, as conceived by him, is confined to the boast of placing the cupola of the Pantheon upon the vaulting of the Temple of Peace. The sketch of it given by Serlio is nothing like the cupola which was executed. On the other hand, what was executed by Michael Angelo was scarcely new after what Brunelleschi had accomplished at Sta. Maria del Fiore. This, however, was a chef d'œuvre of construction; that of St. Peter's was a chef d'œuvre of construction and architecture combined. What was new in it was, that it was the loftiest and largest of all works, ancient or modern, uniting in its vast volume the greatest beauties of proportion to simplicity and unity of form; to magnificence and richness of decoration a symmetry which gives harmony to the whole, considered by itself, and not less so when considered in relation to the mass of which it is the crown. The great superiority of this cupola over all others is visible in another point of view, which we shall more particularly notice in the account of St. Paul's in a subsequent page: it is, that the same masonry serves for the exterior as well as the interior, whereby an immense additional effect is gained in surveying it from the inside. All is fair; there is no masking, as in other cupolas that followed it.

341. Whatever opinions may be formed on the other works of Michael Angelo, no difference can exist respecting the cupola of St. Peter's. "Si tout," observes De Quincy, "ce qui avait été fait et pensé, ou projeté avant lui, en ce genre, ne peut lui disputer le prix de l'invention et de l'originalité, et ne peut servir qu'à marquer la hauteur de son génie, il nous semble que les nombreuses coupoles élevées dans toute l'Europe depuis lui et d'après lui, ne doivent se considérer encore que comme autant d'échelons, propres à faire mieux sentir et mesurer sa superiorité." The bungling of Carlo Maderno at St. Peter's is much to be regretted. The arches he added to the nave are smaller in dimensions than those which had been brought up immediately adjoining the piers of the cupola; and, what is still more unpardonable, the part which he added to the nave is not in a continued line with the other work, but inclines considerably to the south: in other words, the church is not straight, and that to such an extent as to strike every educated eye. His taste, moreover, was exceedingly bad.

342. In the principal churches of Rome there is great similarity of plan; they usually consist of a nave and side aisles, in which latter, chapels are ranged along the sides. The separation of the nave and aisles is effected by arcades. The transepts are not much extended, and over the intersection of them with the nave and choir a cupola generally rises. The chapels of the Virgin and Holy Sacrament are commonly in the transepts; and the great altar is at the end of the choir, which usually terminates semicircularly on the plan. Unlike those of the Florentine school, the interiors of the Roman churches are decorated to excess. Pictures, mosaics, and marbles of every variety line the walls. A profusion of gilding imparts to them a richness of tone, and the architectural details are often in the highest state of enrichment. They are, indeed, temples worthy of the worship of the Deity. Yet, with all this magnificence, the façades are often mean; and when a display of architecture is exhibited in them, it is produced by abuses of the worst class. They are generally mere masks; for between the architecture of these false fronts and that of the interior there is no architectural connection. In very many instances the sides of the churches are actually hidden by adjacent buildings, so that they are altogether unseen; a circumstance which may have conduced to the repetition of the abuse. Faulty, however, as these edifices are, to them is Europe indebted as models, which have in modern times been more purified. We have not space to enumerate or criticise the churches with which Rome abounds. St. Carlo on the Corso, by Onorio Langhi, is a fine example of them, and gives a fair notion of the general distribution we have described. Those of a later date, especially those by Borromini, may be considered as *indices rerum vitandarum* in architecture; and though we are, perhaps, from the cupidity of upholsterers and house decorators, likely to be doomed to sit in rooms stuffed with the absurdities of the taste prevalent in the time of Louis XV., we can hardly conceive it necessary in these days to recommend the student's abhorrence of such freaks of plan and elevation as are to be found in the church of St. Carlo alle quattro Fontane, by that architect.

343. The palaces of Rome are among the finest architectural works in Europe; and of those in Rome, as we have before observed, none equals the Farnese, whose façade is given in *fig.* 169. "Ce vaste palais Farnese, qui à tout prendre, pour la grandeur de la masse, la regularité de son ensemble, et l'excellence de son architecture, a tenu jusqu'ici, dans l'opinion des artistes, le premier rang entre tous les palais qu'on renomme," is the general description of it by De Quincy, upon whom we have drawn largely, and must continue to do so. This edifice, by San Gallo, forms a quadrangle of 256 ft. by 185 ft. It is constructed of brick, with the exception of the dressings of the doors and windows, the quoins of the fronts, and the entablature and loggia in the Strada Giulia, which are of travertine stone. Of the same stone, beautifully wrought, is the interior of the court. The building consists of three stories, including that on the ground, which, in the elevations or façades, are separated by impost cornices. The only break in its symmetry and simplicity occurs in the loggia, placed in the centre of the first story, which connects the windows on each side of it by four columns. On the ground story the windows are decorated with square-headed dressings of extremely simple design; in the next story they are flanked by columns, whose entablatures are crowned alternately with triangular and circular pediments; and in the third story are circular-headed windows, crowned throughout with triangular pediments. The taste in which these last is composed is not so good as the rest, though they were probably the work of Michael Angelo, of whose cornice to the edifice Vasari observes, "È stupendissimo il corniccione maggiore del medesimo palazzo nella

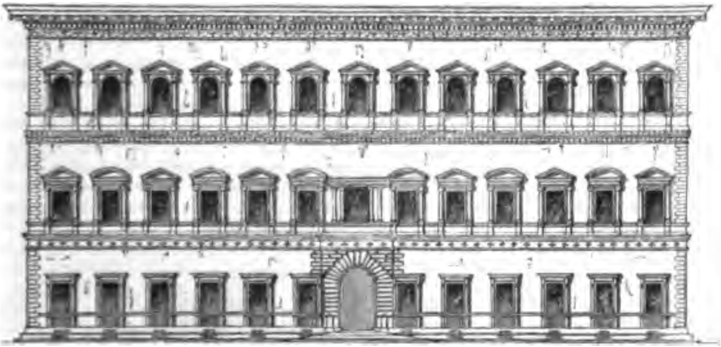


Fig. 169. FARNESE PALACE.

facciata dinanzi, non si potendo alcuna cosa ne più bella ne più magnificà desiderare." The façade towards the Strada Giulia is different from the other fronts in the centre only, wherein there are three stories of arcades to the loggia, each of whose piers are decorated with columns of the Doric, Ionic, and Corinthian orders in the respective stories as they rise, and these in form and dimensions correspond with the three ranks of arcades towards the court. It appears probable that this central arrangement was not in the original design of San Gallo, but introduced when the third story was completed. Magnificent as from its simplicity and symmetry is the exterior of this palace, which, as De Quincy observes, " est un édifice toujours digne d'être le sejour d'un prince," yet does it not exceed the beauty of the interior. The quadrangle of the court is 88 ft. square between the columns of the arcades, and is composed with three stories, in which the central arrangement above mentioned towards the Villa Giulia is repeated on the two lower stories, over the upper whereof is a solid wall pierced in the windows. The piers of the lower arcade are ornamented with Doric columns, whose entablature is charged with triglyphs in its frieze, and its metopæ are sculptured with various symbols. The imposts of the piers are very finely profiled, so as to form the entablatures when continued over the columns of the entrance vestibule. In the Ionic arcade, over this, the frieze of the order is decorated with a series of festoons. The distribution of the different apartments and passage is well contrived. All about the building is on a scale of great grandeur. Though long unoccupied, and a large portion of its internal ornaments has disappeared, it still commands our admiration in the Carracci Gallery, which has continued to serve as a model for all subsequent works of the kind. The architecture of the Farnese palace, more especially as respects the arcades of its court, is the most perfect adaptation of ancient arrangement to more modern habits that has ever been designed. We here allude more particularly to the arcades, upon whose piers orders of columns are introduced. This species of composition, heavier, doubtless, less elegant, yet more solid than simple colonnades, is, on the last account, preferable to them, where several stories rise above one another. The idea was, certainly, conceived from the practice in the ancient theatres and amphitheatres; and in its application at the Farnese palace rivals in beauty all that antiquity makes us in its remains acquainted with. San Gallo, its architect, died in 1546.

344. It would be impossible here to enumerate the palaces with which Rome abounds; but we must mention another, that of St. Giovanni Laterano, by Domenico Fontana, as a very beautiful specimen of the palatial style. Milizia censures the detail of this edifice, and there is some truth in his observations in that respect; but the composition is so simple and grand, and the cornice crowns it with so much majesty, that the detail is forgotten in the general effect, and its architect well deserves the rank of a great artist.

345. The villas, *Ocelli d'Italia*, as they have been called, round the suburbs of Rome, are in a style far lighter than the palaces whereof we have just been speaking. They are the original models of the modern country houses of this island, and exhibit great skill in their plans and elegance in their façades. Generally they rose from the riches and taste of a few cardinals, who studded the environs of the Eternal City with some of the fairest gems of the art. MM. Percier and Fontaine published a collection of them at Paris, from which we extract the Villa Pia (*fig.* 170.). It was designed by Pirro Ligorio, a Neapolitan

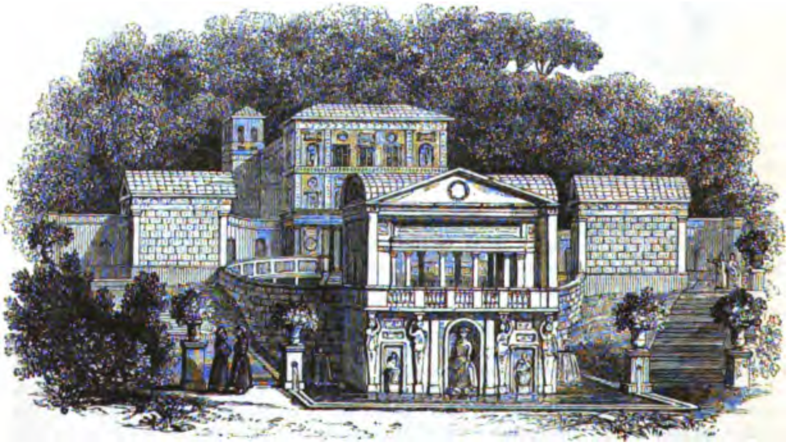


Fig. 170. VILLA PIA.

architect, who died in 1580, and is thus described by the authors whose view of it we have borrowed. "It was built," say they, "in imitation of the houses of the ancients, which Ligorio had particularly studied. This clever artist, who to his talent as an architect joined the information of a learned antiquary, here threw into a small space every thing that could contribute to render it a delightful dwelling. In the midst of verdant thickets, and in the centre of an amphitheatre of flowers, he constructed an open lodge, decorated with stuccoes and agreeable pictures. The lodge is raised upon a base, bathed by the water of a basin, enclosed with marbles, fountains, statues, and vases. Two flights of steps, which lead to landings sheltered by walls ornamented with niches and seats of marble, offer protection from the sun's rays by the trees that rise above them. Two porticoes, whose interior walls are covered with stuccoes, lead on each side to a court paved in mosaic work. This is enclosed by a wall, round which seats are disposed. Here is a fountain spouting up from the centre of a vase of precious marble. At the end of the court facing the lodge an open vestibule, supported by columns, fronts the ground floor of the principal pavilion; and is decorated with mosaics, stuccoes, and bassi-relievi of beautiful design. The apartments on the first floor are ornamented with fine pictures. Finally, from the summit of a small tower, which rises above the building, the view extends over the gardens of the Vatican, and the plains through which the Tiber takes its course, and the splendid edifices of Rome." For further information on the Roman villas, we refer the reader to the work we have quoted.

346. The Roman school of architecture, founded by Bramante, includes San Gallo, Buonarroti, Sansovino, Peruzzi, Vignola (whose extraordinary palace at Caprarola deserves the study of every architect), and many others. It ends with Domenico Fontana, the period of its duration being from 1470 to 1607, or little more than 130 years.

347. Before we proceed to the Venetian school, it will, however, be proper to notice two architects, whose works tended to change much for the worse the architecture of their time; we mean Borromini and Bernini, though the latter was certainly purer in his taste than the former. Borromini, whose example in his art was followed throughout Europe, and who, even in the present day, has his returning admirers, was the father of all modern abuses in architecture; and the reader must on no account confound his works with those of the Roman school, which had ceased nearly half a century before the native of Bissona had begun to practise. He inverted the whole system of Greek and Roman architecture, without replacing it by a substitute. He saw that its leading forms, sprung from a primitive type, were, by an imitation more or less rigorous, subjected to the principles of the model from which its order and arrangement emanated. He formed the project of annihilating all idea of a model, all principles of imitation, all plea for order and proportion. For the restriction in the art resultant from the happy fiction, or perhaps reality of a type, one whose tendency was to restrain it within the bounds of reason, he substituted the anarchy of imagination and fancy, and an unlimited flight into all species of caprice. Undulating flexibility supplanted all regularity of form; contours of the most grotesque description succeeded to right lines; the severe architrave and entablature were bent to keep up the strange delusion; all species of curves were adopted in his operations, and the angles of his buildings were perplexed with an infinite number of breaks. What makes this pretended system of novelty more absurd is (and we are glad to have the opportunity here of observing that the remarks we are making are applicable to the present fashionable folly of decorating rooms *à la Louis XIV.* and *XV.*), that its only novelty was the disorder it introduced, for Borromini did not invent a single form. He was not scrupulous in retaining all the parts which were indicated by imitating the type; he decomposed some, transposed others, and usually employed each member in a situation directly the reverse of its proper place, and, indeed, just where it never would be naturally placed. Thus, for example, to a part or ornament naturally weak, he would assign the office of supporting some great weight; whilst to one actually capable of receiving a great load, he would assign no office whatever. With him every thing seems to have gone by contraries; and to give truth the appearance of fiction, and the converse, seems to have been his greatest delight. Out of all this arose a constant necessity for contrivance, which marked Borromini as a skilful constructor, in which respect he attained to an extraordinary degree of intelligence. It seems, however, not improbable that one of his great objects in studying construction was, that he might have greater facility in carrying his curious conceits into execution; for it may be taken almost as an axiom in architecture, so great is the relation between them, that simple forms and solid construction are almost inseparable; and it is only necessary to have recourse to extraordinary expedients in construction when our productions result from an unrestrained imagination. Further notice of this architect is not necessary; one of his most celebrated works is the restoration of the church of St. Giovanni Laterano, — after St. Peter's, the greatest in Rome. His purest work is the church of St. Agnese; whilst that of St. Carlo alle quattro fontane, which we have heretofore noticed, is the most *bizarre*. Borromini died in 1667.

348. Bernini, the other artist whom we have mentioned, was equally painter, sculptor,

and architect; his principal work is the colonnade in front of St. Peter's. He was, notwithstanding the abuses to be found in his works, a man of great talent. In their general arrangement his buildings are good and harmonious; his profiles are graceful; his ornaments, though sometimes profuse, are usually elegant. Bernini, however, was no check upon the pernicious character of his cotemporary Borromini; instead, indeed, of relieving architecture of some of her abuses, he encumbered her with fresh ones. He was also fond of broken pediments, and of placing them in improper situations. He employed undulations, projections innumerable, and intermixtures of right lines with curves; for beautiful simplicity he substituted elegant fancy; and is to be imitated or admired by the student no farther than he followed nature and reason. He made some designs for the Louvre at Paris, which are exceedingly good. His death occurred in 1680.

349. 3. *The Venetian School* is characterised by its lightness and elegance; by the convenient distribution it displays; and by the abundant, perhaps exuberant, use of columns, pilasters, and arcades, which enter into its composition. Like its sister school of painting, its address is more to the senses than is the case with those we have just quitted. We have already given an account of the church of St. Mark, in the 12th century; from which period, as the republic rose into importance by its arms and commerce, its arts were destined to an equally brilliant career. The possession in its provinces of some fine monuments of antiquity, as well as its early acquaintance with Greece, would, of course, work beneficially for the advancement of its architecture. That species of luxury, the natural result of a desire on the part of individuals to perpetuate their names through the medium of their habitations, though not productive of works on a grand or monumental scale, leads, in a democracy (as were the states of Venice), to a very general display of moderately splendid and elegant palaces. Hence the extraordinary number of specimens of the building art supplied by the Venetian school.

350. San Micheli, who was born in 1484, may, with propriety, be called its founder. Having visited Rome at the early age of sixteen for the purpose of studying its ancient monuments of art, and having in that city found much employment, he, after many years of absence, returned to his native country. The mode in which he combined pure and beautiful architecture with the requisites called for in fortifications may be seen displayed to great advantage at Verona, in which city the *Porta dell Pallio* is an instance of his wonderful ingenuity and taste. But his most admired works are his palaces at Verona; though, perhaps, that of the Grimani family at Venice is his most magnificent production. The general style of composition, very different from that of the palaces of Florence and Rome, is marked by the use of a basement of rustic work, wherefrom an order rises, often with arched windows, in which he greatly delighted, and these were connected with the order after the manner of an arcade, the whole being crowned with the proper entablature. As an example, we give, in *fig.* 171., the façade of the Pompei palace at Verona. The genius of San Micheli was of the very highest order; his works are as conspicuous for excellent construction as they are for convenience, unity, harmony, and simplicity, which threw into shade the minor abuses occasionally found in them. If he had no other testimony, it would be sufficient to say, that for his talents he was held in great esteem by Michael Angelo; and our advice to the student would be to study his works with diligence. San Micheli devoted himself with great ardour to the practice of military architecture; and though the invention was not for a long time afterwards assigned to him, he was the author of the

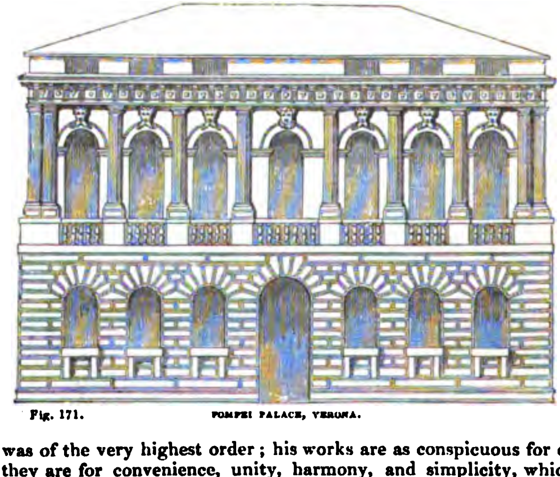


Fig. 171. POMPEI PALACE, VERONA.

system used by Vauban and his school, who, for a long period, deprived him of the credit of it. Before him all the ramparts of a fortification were round or square. He introduced a new method, inventing the triangular and pentangular bastion, with plain fossés, flanks, and square bases, which doubled the support; he moreover not only flanked the curtain, but all the fossé to the next bastion, the covered way, and glacis. The mystery of this art consisted in defending every part of the inclosure by the flank of a bastion; hence, making it round or square, the front of it, that is, the space which remains in the triangle, which was before undefended, was by San Micheli provided against. We cannot, however, further proceed on this subject, which belongs to military, which at that period was intimately connected with civil architecture. The *Porta del Pallio* at Verona has been mentioned; that city, however, contains another gate of great architectural merit by this master, the *Porta Nuova*, a square edifice, supported within by a number of piers of stone, with enclosures or apartments for the guards, artillery, &c. The proportions, as a whole, are pleasing; it is of the Doric order, devoid of all extraneous ornament, solid, strong, and suitable to the purposes of the building. Except in the middle gate and the architectural parts, the work is rusticated. The exterior façade stands on a wall, with two large pyramidal pilasters of marble rising from the bottom of the fosse; at the top are two round enclosures approaching almost to towers. In the interior, to the two gates near the angles are two corresponding long passages, vaulted, leading to a number of subterraneous galleries and rooms. For beauty, however, we do not think this gate so beautiful as that of del Pallio, which we here give (*fig.* 172.). But the gem of this great master is the little circular chapel at San Bernardino, whose beauty, we think, has scarcely ever been surpassed, and which exhibits, in a striking degree, the early perfection of the Venetian school. It was not finished under San Micheli, and blemishes are to be found in it; it is nevertheless an exquisite production, and, in a surprisingly small space, exhibits a refinement which elsewhere we scarcely know equalled. The works which he designed surpass, we believe, in number those of all the masters of Italy, Palladio, perhaps, excepted. He gave a tone to his art in the Venetian states, which endured for a considerable period. His death occurred in 1549.

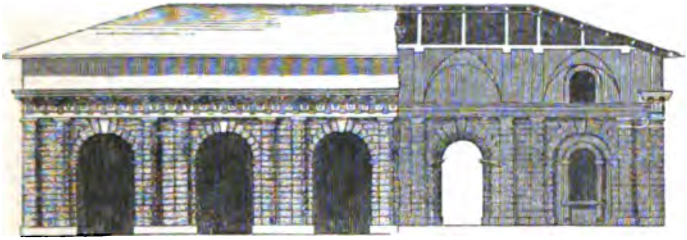


Fig. 172. PORTA DEL PALLIO, VERONA.

351. Contemporary with San Micheli, was another extraordinary genius of this school, born at Florence,—Jacopo Tatti by name, but more usually called Sansovino, from the country of his master, Andrea Contucci di Monte Sansovino. Such was the respect for this artist in Venice, his adopted city, that at a moment when it became necessary to raise by means of taxation a large sum on the citizens, the senate made a special exemption in favour of him and Titian. The Roman school might lay claim to him, if the works he executed at Rome, and not his style, would justify it; but that is so marked, so tinctured with the system of arcades with orders, its distinguishing feature, that an inspection of his works will immediately satisfy even a superficial observer. He was a great master of his art; and though he does not in so great a degree appear to have profited by the examples of antiquity as the architect last named, he has left behind buildings, which, for picturesque effect, leave him little inferior in our rating. He was the architect of the library of St. Mark at Venice, a portion whereof is given in *fig.* 173.; a building of noble design, notwithstanding the improprieties with which it is replete. It consists of two orders; the lower one of highly ornamented Doric, and the upper one Ionic and very graceful in effect. Of both these orders, as will be seen in the figure, the entablatures are of inordinate comparative height. The upper one was expressly so set out for the purpose of exhibiting the beautiful sculptures with which it is decorated. The cornice is crowned with a balustrade, on whose piers statues were placed by the ablest scholars of Sansovino. A portico occupies the ground floor, which is raised three steps from the level of the piazza. This portico consists of twenty-one arcades, whose piers are decorated with columns. In the interior are arches corresponding to the external ones, sixteen whereof, with their internal apartments, are appropriated for shops. Opposite the centre arch is a magnificent staircase leading to the hall, beyond which is the library of St. Mark. The

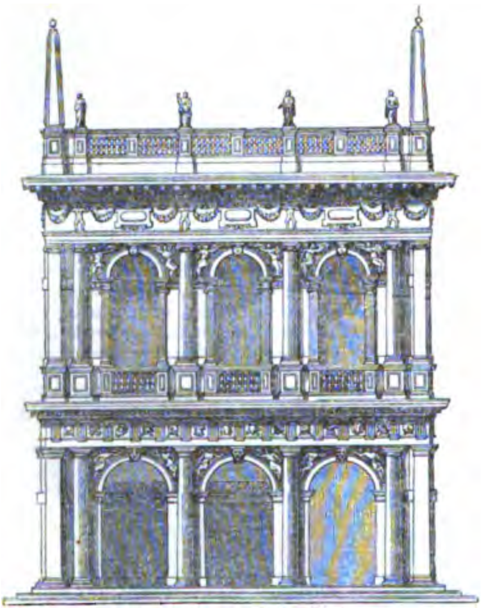


Fig. 173. LIBRARY OF ST. MARK.

faults of this building, which are very many, are lost in its grace and elegance, and it is perhaps the chef d'œuvre of the master. Whilst Sansovino was engaged on it he propounded an architectural problem, which reminds us very much of the egg of Columbus: "How can the exact half of a metope be so contrived as to stand on the external angle of the Doric frieze?" The solution, clumsy as that of the navigator with his egg, practised in this building, is, however, a bungling absurdity; namely, that of lengthening the frieze just so much as is necessary to make out the deficiency. Sansovino was invited to pass into France, where he gave some designs, which tended to the advancement of the art in that country. On his return he built the Zecca, or mint, one of his finest works. Another of his extraordinary productions is the palace of the Comari, on the Grand Canal at San Maurizio. The church of San Fantino, among the finest of Venice, is also by him; as is that of San Martino and many others. Jacopo was fertile in invention: his architecture was full of grace and elegance; but he was deficient in a thorough knowledge of construction, which, in the library of St. Mark, brought him into disgrace, of which, from all accounts, the builders ought to have suffered the principal share. He continually introduced the orders, and especially the Doric and Composite. The members of his entablatures were much sculptured; but his ornaments were extremely suitable and correct. In statues and bassi relievi he greatly indulged, thereby adding considerably to the effect and majesty of his buildings. Scamozzi mentions a work by him on the construction of floors, and particularly describes a method adopted by him for preventing dust falling through the joints of the boards. The work has been lost. Sansovino died in 1570.

352. After such artists as San Micheli and Sansovino, it would have seemed to an ordinary mind difficult to have invented new forms, or rather so to have modified the old ones as to be original. Andrea Palladio, however, not only knew how to be original, but to leave his works as models for the countries of Europe, in which the style which bears his name has had no rival; so true is it, in all the arts, that there is always room to be found for a man on whom nature has bestowed the faculty of seeing, feeling, and thinking for himself. In the case of the architect something more than genius is necessary: it is requisite that circumstances should exist by which his art may be developed, or, in other words, that what he is capable of producing may at the time be suitable to the wants of society. Such circumstances existed for a long period in Italy, where, up to the time at which we are arrived, the rich and great had been contending with the governments which should be the greatest patrons of the art. Hence sprung the multitude of extraordinary works in the country named, which still point out the greatness in art at which it had arrived, when it was one of the really necessary arts. Neither in the Venetian states, nor at the time when he rose into reputation, which was about the middle of the sixteenth century, had Palladio that opportunity of signalising himself which had occurred to many former masters. Venice had risen into power and wealth by its arms and commerce; was the natural protectrix of the art; and although the works she required were not on scales of the grandest dimensions, yet those which her citizens required kept pace in luxury with the increasing wealth of the families by whom they were required. This was the career open to the genius of Palladio. Architecture in these states was not called upon to furnish churches of colossal dimensions, nor palaces for sovereigns, nor immense public monuments left for posterity to finish. The political state of the country, very luckily for his talents, furnished a numerous class of citizens who contended which should procure for himself the aid of this great man in rearing a villa or palace, and which might serve the

double purpose of a present dwelling for, and a future memorial of, his family,—a passion that covered the banks of the Brenta with edifices which, of their class, form a complete school of civil architecture.

353. The taste of Palladio was tempered by the care he bestowed on accommodating exterior beauty to interior convenience, and by suiting the art to the wants of persons with moderate means, through the medium of greatness without great dimensions, and richness of effect without great outlay. In the imitation, or rather appropriation, of the architecture of the ancients, none of his predecessors of any of the schools had so luckily hit on that just medium of exactness without pedantry, of severity without harshness, of liberty without licentiousness, which have since made the architecture of ancient Greece popular, and so modified it as to be practicable and convenient in all countries. We here speak, of course, of the elements, and not the combinations, of Greek art, and of it changed by a passage through an intermediate state during the existence of the Roman empire. No architect can consider himself thoroughly educated who has not studied the works of Palladio. "De fait," says De Quincy, in his Life of this architect, "il n'est point d'architecte qui, après avoir formé ou réformé son style sur les grands modèles de l'art des anciens, et des premiers maitres de l'Italie moderne, ne se croie pas obligé d'aller encore étudier dans la patrie et les œuvres de Palladio, un genre d'applications plus usuelles, et plus en rapport avec l'état de nos mœurs; c'est-a-dire, le secret d'accommoder tour-à-tour, et nos besoins aux plaisirs d'une belle architecture, et l'agrément de celle-ci aux sujétions que de nouveaux besoins lui imposent." It was from the peculiar properties of Palladio's taste and style, suited as they are to more moderate fortunes, that they found in England a second native country (if such an expression may be allowed), where Inigo Jones, Wren, Gibbs, Taylor, Chambers, and many others, have naturalised the plans, façades, distribution, and details which were originally planted in the provinces of the Venetian republic. Indeed, the style of Palladio could not be prevented from spreading through Europe, as being a mean between the severe use of ancient forms and the licentious style of those who reject all rules whatever. The buildings by him exhibit great good sense, simple means of accomplishing the end, a satisfactory agreement between the demands of necessity and pleasure, and such an harmony between them that it is hard to determine which has submitted to the other. The interior distribution of his palaces and villas in respect of plan would, without considerable modification, be but ill suited to modern habits. We give, in *fig.* 174. (*see next page*), a plan and elevation of the Villa Capra, one of his most celebrated works of that class. Convenience changes as the mode of life varies; indeed, except in a private building of large extent, the large quadrangular court of the houses of Italy is here unknown. Palladio's plans, however, were convenient to those for whom they were executed; and in that way they must be judged. With his eyes constantly turned to the practice and detail of the ancients, he acquired a bold, simple, and agreeable style; and, his churches excepted, the beauties of the master are to be sought in his façades, and the quadrangles of his palaces. Pedestals, either with panels or raisings, were always avoided by him; his architraves were rarely sculptured; and the upper ornaments of his entablatures were always carefully centred above each other. His doors, windows, and niches are composed with great simplicity; and pediments, when used, are unbroken. In the members of his cornices he never lost sight of the character of the order employed, and was extremely particular in duly adjusting its profiles. He, however, did not scruple to vary the proportions of an order according to the nature of the building to which it was applied; and in the proportions of his churches and apartments he seems to have delighted, as afterwards did Sir Christopher Wren, in arithmetical, geometrical, and harmonic proportions. Though extremely partial to the use of the Ionic order, yet the others were not unfrequently used by him. His Corinthian capital is not to be praised; it is profiled very clumsily, and ought not to be followed. The domes which he erected are almost invariably hemispherical. It is not to be supposed that his buildings are perfect, though they approach perfection; but it is more than probable that many of the abuses we see in them arose either from want of sufficient superintendence, the number he designed being very great, or that they were introduced after his death. This, we think, may be safely assumed, because the instructions in his work on architecture are very peremptory on the subject of abuses. So well based upon the practice of the ancients does the style of our master appear to be, that it is, with but few modifications, suited to all nations, and just such as the ancients themselves would have adopted. "Les fermes," observes Le Grand in his parallèle, "que dirigeait Palladio et qu'il couvrait de tuiles on d'un chaume rustique, l'emportent de beaucoup sur les palais somptueux de Borromini, ou sur les riches et bizarres productions de Guarino Guarini." Certain, indeed, it is that simplicity, unity, and style are more powerful means of producing grandeur, than great volume or large masses unskilfully handled. A fine instance of this is seen in the façade of the Thiene palace at Vicenza, *fig.* 175. (*See next page.*)

354. The number of palaces and villas with which Palladio enriched the Venetian and Vicentine territories is almost incredible: the variety of plan and elevation in them seems as inexhaustible as their number. To the buildings above referred to may be added the

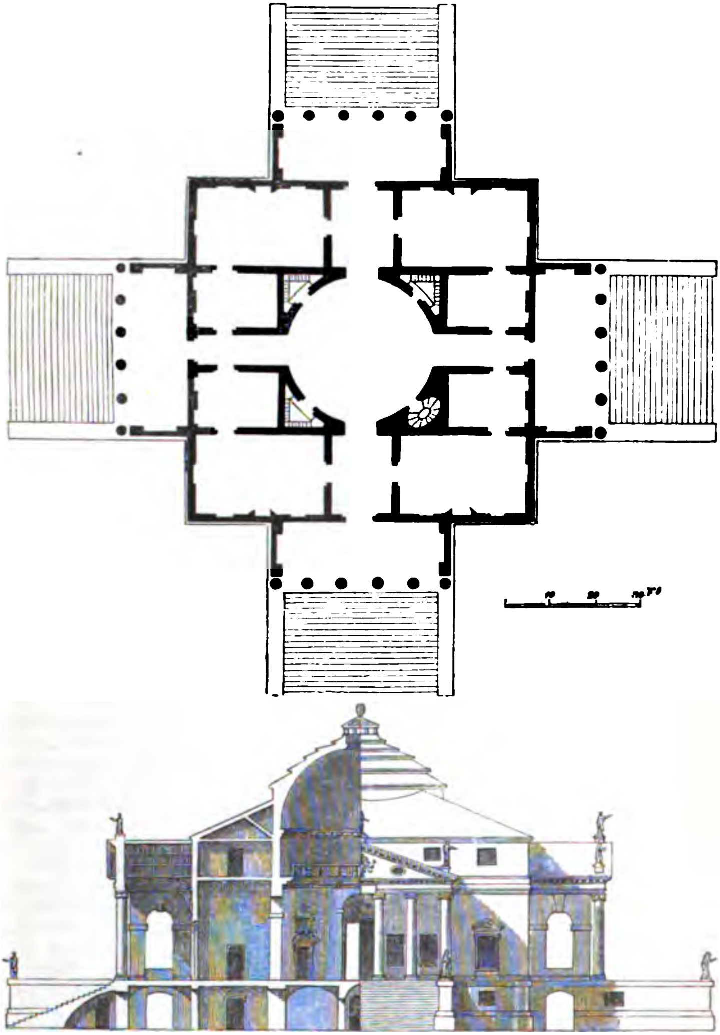


Fig. 174. PLAN, ELEVATION, AND SECTION OF VILLA CAPRA.

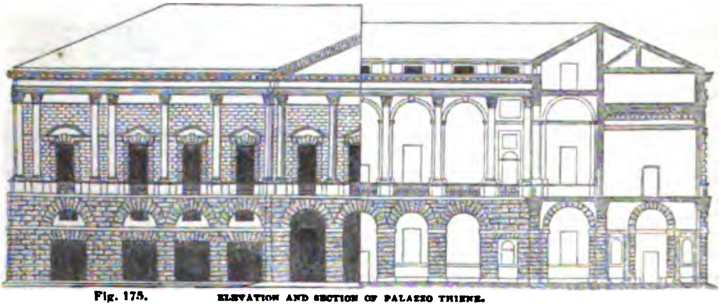


Fig. 175. ELEVATION AND SECTION OF PALAZZO THIENE.

Carità at Venice, which is a lovely specimen of his style. His grandest church is that Del Redentore at Venice. Generally in the façades of his churches there are abuses, whereof it is scarcely credible he would have been guilty: such are the two half pediments in the church we have just mentioned. The theatre built upon the ancient model for the Olympic Academy at Vicenza gained great reputation for him. Palladio died in 1580.

355. The last architect of the Venetian school who obtained celebrity was Vincenzo Scamozzi. The son of an architect, and born in a country which had become the nursery of the art, his powers were exhibited at an early age. Like Palladio and other great masters, he selected for his principal guides the antiquities of the Eternal City, and the precepts of Vitruvius, whose work at that period was considered of high importance, as in truth it really was. There is no doubt that Scamozzi was much indebted to the works of Palladio, although he affected occasionally to decry them; but, in opposition to De Quincy, we think that his style is more founded on that of San Micheli or Sansovino. This is, however, of little importance; for his natural talents were of a very high order. At a very early period of his career, so great was his reputation that he was employed by the canons of San Salvadore in opening the lantern to the cupola of their church; a task in which it appears that he acquitted himself with great ability. For the upper order of the Procurazie Nuove at Venice he has often been unjustly reproached, because he did not confine himself to two stories, so as to complete the design of Sansovino. The design of Scamozzi, had it been continued in the Piazza San Marco, would have placed in the back ground every other piazza in Europe. The two lower stories of the Procurazie Nuove are similar in design to the Library of S. Marco; and it is greatly to be regretted that Scamozzi was so much otherwise occupied that he had not the opportunity of watching the whole of its execution, which would have extended to thirty arcades, whose whole length would have been 426 feet. Scamozzi only superintended the first thirteeen; the three built by Sansovino excepted, the rest were trusted to the care of builders rather than artists, and, from the little attention bestowed upon preserving the profiles, exhibit a negligence which indicates a decline in the arts at Venice. Scamozzi is placed in the first rank as an architect by his design for the cathedral at Saltzburg, whither he was invited by the archbishop of the see. This church, which was not completed till after his death in 1616, is 454 ft. long, and 329 ft. wide, being in the form of a Latin cross on the plan, over whose centre a cupola rises. The distribution of the interior is with a nave and two side aisles; the former whereof is 64 ft. wide, and 107 ft. high. Scamozzi's employment was very extended, and his country has to lament it; for fewer commissions would have insured greater perfection in their execution, which, in those that exist, is often unworthy of the name of the master. Scamozzi published a work on the art, which will be found in our list of authors at the end of this work. He died in 1616.

356. Besides Giovanni da Ponte and Alessandro Vittoria, the Venetian school contains the names of few more than those we have named: they appear to have commanded the whole of the employ of the states and neighbourhood of Venice for a period of about 110 years, ending in 1616. When, however, it no longer continued to grow and flourish in its native soil, its scions, grafted throughout Europe, spreading their branches in every country, prospered wherever they appeared. On the former of the two architects just named, a few observations are necessary. He died in 1597, at the age of eighty-five years. Principally occupied in the reparation and re-establishment of the buildings of the city that had fallen into decay, he was nevertheless engaged on some considerable works; among which was the great hall of the arsenal at Venice, 986 feet long, and the more celebrated work of the Rialto Bridge, whence he obtained the sobriquet *Da Ponte*, and for the execution whereof he competed with Palladio and Scamozzi. The span of the single arch of which the work consists is about 72 ft., and the thickness of the arch stones about 4 ft. 4 in. It is segmental, and the height from the level of the water is about 22 ft. 9 in. The width of the bridge is equal to the span of the arch, and this width is divided longitudinally into five divisions, that is, into three streets or passages, and two rows of shops. The middle street or passage is 21 ft. 8 in. wide, and the two side ones near 11 ft. The number of shops on it is twenty-four. The last work of Da Ponte was the construction of the prisons away from the ducal palace. This edifice is a quadrilateral building, with a portico of seven arcades. A story rises out of it pierced by seven great windows decorated with pediments, and it is joined to the palace by the bridge so well known under the name of *Il Ponte dei Sospiri*. The work was not carried to completion during Giovanni's life, but was finished by his nephew Contino. In his church on the Grand Canal, constructed for the nuns of Santa Croce, there is little merit except that of solidity; indeed, he does not appear to have possessed much taste, as may be inferred from the two ranks of columns in the hall of the arsenal above mentioned, which cannot be said to belong to any of the species of columns usually employed. The solid character of the great prison is appropriate, and more in consonance with the rules of the art.

Sect. XVII.

FRENCH ARCHITECTURE.

357. The architecture of Europe from the middle of the sixteenth century was founded on that of Italy. Of its value, the French and the English seem to have a stronger perception than the rest of the nations. We shall therefore now consider the architecture of France: that of England from a much earlier date will be separately considered in the succeeding chapter. Philibert Delorme was among the first of the architects of France who promoted a taste for good architecture; and though in some respects he may have been surpassed by other artists of his time, in others, whether connected with theory or practice, he has left his rivals a great distance behind him. Although he might not have had the purity of detail of Jean Bullant, nor the richness of invention and execution of P. Lescot, he has acquired by his talent in construction a reputation which has survived his buildings. The Queen Catherine of Medicis having resolved upon the construction of a palace at Paris, which should far surpass all that had previously been done in France, resolved upon placing it on a spot then occupied by some tile kilns (Tuileries) in the faubourg St. Honoré, and committed the design and erection to Delorme. It is, however, contended by some that Jean Bullant was joined with him in the commission. If that was really the case, it is probable that the labours of the latter were confined to details of ornament and execution, rather than to the general design and disposition. What, if it was so, belonged to each is not now to be discovered; but the genius of Delorme has survived all the revolutions the celebrated building in question has undergone. Catherine seems not to have been satisfied with the works; for she appears to have begun another palace on the site of the Hotel Soissons, that of the present Halle au Bleds, and to have entrusted this to the care of Jean Bullant. That of the Tuileries was in the end continued by Henri IV.; enlarged by Louis XIII. on the same line, after the designs of Du Cerceau, with two main bodies and two composite pavilions; all which were in the time of Louis XIV. afterwards brought together by the designs of Leveau and Dorbay. In the centre pavilion all that now remains of Delorme's work is the lower order of Ionic columns. This morsel of Delorme exhibits a good Ionic profile in the order, and is one of his best works. Generally speaking, the profiles of this master, which Chambrai has admitted into his *Parallèle*, make one acknowledge the justice of that author's observation, that he had "un peu trop vu les plus belles choses de Rome, avec des yeux encore préoccupés du style Gothique. Le talent de cet architecte consistait principalement dans la conduite d'un bâtiment, et de vrai il était plus consommé en la connaissance et la coupe des pierres que dans la composition des ordres; aussi en a-t-il écrit plus utilement et bien plus au long." Delorme was the author of two works on architecture: one, *Un Traité complète de l'Art de Bâtir*, on architecture generally; the other, *Nouvelles Inventions pour bien bâtir et à petits frais*. The last relates more especially to a practice in carpentry, which, on the Continent, has been put into execution with great success, its principle being still constantly applied. The method of carpentry invented by Delorme, and which still goes in France by his name, consists in substituting for the ordinary system of framing and rafters curved ribs, in two thicknesses, of any sort of timber, three or four feet long, and one foot wide, of an inch in thickness, and which are connected in section and tie according to the form of the curve, whether pointed, semicircular, or segmental. These arches, in order to be strong and solid, should be fixed at their feet on plates of timber framed together, lying very level on the external walls; and the planks which are to form the principal curve are to be placed accurately upright on their ends, in which situation they may be kept by braces morticed into them at convenient distances, and retained in their places by wedges, for it is essential to the strength of this species of carpentry that it should be kept in a vertical position. In this country the species of carpentry just mentioned has never been practised to the extent it deserves. Delorme died in 1570. With him was cotemporary Jean Bullant, whose name has been just mentioned, and who, whilst San Gallo was occupied on the Palazzo Farnese, was raising the Château d'Ecouen, in which the prelude to good taste is manifest, and in whose details are exhibited the work of an architect very far advanced above his time, and capable of raising the art to a much higher pitch of excellence than it enjoyed, had not the habits of the nation restrained him in his useful course. A considerable portion of the façade of the Tuileries towards the Carousel is suspected to have been the work of Bullant; but the château of Ecouen, built, or rather begun, about 1540, for the constable Montmorency, was almost the first step to the establishment of pure architecture in France, and its architect may fairly be named the Inigo Jones of the French.

358. By the wars in Italy under Charles VIII., Louis XII., and Francis I., the French had become intimately acquainted with the architecture of Italy, and the taste of the monarch last named induced him to bring from that country some of their most celebrated artists; so that in France there was almost a colony of them. Among them, fortunately

for the quicker working of good taste, was the celebrated Vignola, who resided in France many years; a circumstance which may, with some probability, account for the high esteem in which that great master's profiles have always been held, and indeed in which they are still held there, though, generally speaking, the French have invariably been more attached in their practice to the Venetian than to the Roman school. Serlio, another Italian architect of note, was employed in the country by Francis, and actually died at Fontainebleau. At the period whereof we are now treating there appears to have been a number of able artists; for to Delorme and Bullant must be added Lescot, who, with Jean Gougeon as his sculptor, was many years employed upon the building usually called the *Vieux Louvre*, to distinguish it from the subsequent additions which have quadrupled the original project of Lescot. To judge of the works of the French architects of this period, a relative, and not an abstract view, must be taken of them; relative, we mean, to the general cultivation of the arts when any individual artist appears. In this respect Lescot's works at the Louvre are entitled to the greatest praise; and from the examples he as well as Bullant and Gougeon afforded, it might have been expected that pure architecture would have proceeded without check until it reached a point as high as that to which it had been carried in Italy. Such was not, however, to be the case. Mary de Medicis, during her regency, having determined on building the Luxembourg palace, was anxious to have it designed in the style of the palaces of Florence, her native city. Jacques de Brosse, her architect, was therefore compelled to adopt the character required: his prototype seems to have been the Pitti palace, and his version of it is a failure. The gigantic palaces of Florence well enough bear out against the rustic and embossed work employed upon them; but when their scale is reduced, the employment of massive parts requires great caution. The palace, however, of the Luxembourg became a model for the fashion of the day, and produced an intermediate style, which lasted many years in France, and arrested the arrival at perfection whereof the above work of Bullant and others had opened a fair prospect. De Brosse was an able artist, and his design for the façade of St. Gervais of three orders is, under the circumstances, entitled to our praise. This architect acquired much honour by the aqueduct of Arcueil, the completion whereof, in 1624, it is supposed he did not long survive.

359. Under Louis XIV. the art remained for the most part in the intermediate state just noticed; and yet that monarch and his minister Colbert lost no opportunity of embellishing the kingdom with its productions. He employed Bernini to make designs for the palace of the Louvre; and for that purpose induced the artist to visit France, where he was received with the highest respect. He left a design for a façade of the building in question, which, though in a corrupt style, exhibits nevertheless marks of grandeur and magnificence which would have been worthy of the monarch. Bernini, disgusted, as he alleged, with the workmen of Paris, departed from the country without leaving any example of his architectural powers. That he did so France has no reason to lament, since it gave Perrault the opportunity of ornamenting the capital with one of the most splendid monuments of the art which Europe can boast. To Perrault is the credit due of having given an impulse to French architecture it has never lost, and of having changed the heavy style of his time into the light and agreeable forms of the Venetian school. The beauties of the façade of the Louvre (*fig.* 176.) are so many and great that its defects are forgotten. The

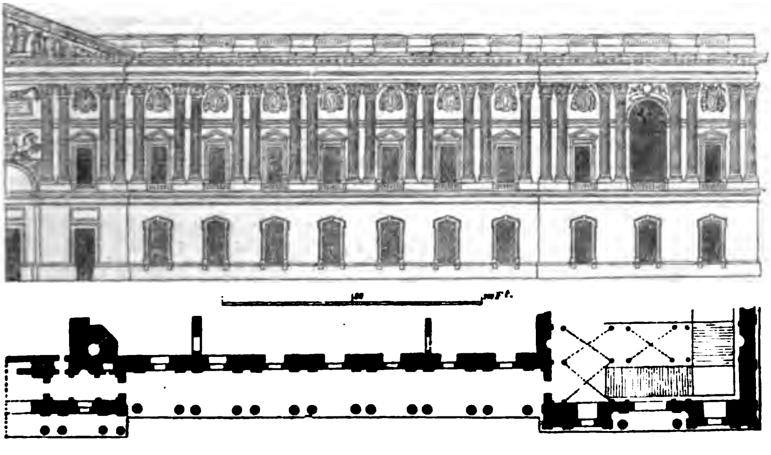


Fig. 176. HALF FACADE AND HALF PLAN OF LOUVRE.

proportions are so exquisite, that the eye cannot rest on the coupled columns and the arch of the principal gate rising into the story of the colonnade. The original profession of Perrault was that of medicine, which, however, he only exercised for the benefit of his friends and the poor; hence the design he made with others in competition for the above work having been successful, he was associated for its execution with Louis le Veau, the king's principal architect. From the variety of sciences in which Perrault excelled, it is not probable that the assistance of a practical architect was actually necessary; indeed the four volumes which he published under the title *Essais de Physique*, and the collection of machines for raising and removing great weights, which he also published, show that he was, without assistance, quite competent to the charge which was committed to him with others. He built the observatory at Paris, possessing an originality of character which Milizia says is very conformable to its purpose. But however suitable it may have been considered at the time of its erection, and it cannot be denied there is a fine masculine character about it, it is for its purpose in the present age altogether ill adapted for the objects of astronomy. Perrault died in 1688. Cotemporary with him was Le Mercier, the architect of the church de l'Oratoire, in the Rue St. Honoré. Le Mercier died, however, in 1660; eight and twenty years, therefore, before the decease of Perrault. Among the architects whose practice was exceedingly extended was Jules Hardouin Mansart, the architect of Versailles, and the especial favourite of Louis XIV. He was principally employed between the years 1675 and his death in 1708. His ability, as Milizia observes, was not equal to the size of his edifices; though it is hardly fair for that author to have made such an observation on the architect of the cupola of the Invalides at Paris. Of this church and dome De Quincy has most truly stated, that though nothing that can be called classic is to be noticed about it, yet it contains nothing in dissonance with the principles of the art. It is a whole in which richness and elegance are combined; in which lightness and solidity are well balanced; in which unity is not injured by variety; and whose general effect silences the critic, however he may be disposed to find fault. In Versailles, the taste which we have above noticed as introduced by De Brosse is prevalent; but the interior of the chapel displays to great advantage the great genius of Mansart, and that he was not incapable of the most refined elegance.

360. Jacques Ange Gabriel was the relation and worthy pupil of Mansart. The colonnades to the Garde Meuble in the Place Louis XV. (now the Place de la Concorde) exhibit a style which, with the only exception of Perrault's façade of the Louvre, not all the patronage of Louis XIV. was capable of eliciting. To Gabriel almost, if not perhaps as much as to Perrault, the nation is under a debt of gratitude for the confirmation of good taste in France. He has been accused of pirating the Louvre; but reflection and comparison will show that there is no real ground for such an accusation. The difference between the two works is extremely wide. The basement of Perrault is a wall pierced with windows; that of Gabriel is an arcade: in the upper stories the columns are not coupled, which is the case at the Louvre. From these circumstances alone the character of the two works is so different, that it is quite unnecessary to enter into other detail. Architecture in France at this period, the commencement of the eighteenth century, was in a palmy state, and has never before or since risen to higher excellence; though the French are still, from the superior method of cultivating the art there, and the great encouragement it receives, the first architects in Europe. The great extent of the Place Louis XV. (744 ft. long, and 522 broad) is injurious to the effect of the Garde Meuble, which, as the reader will recollect, is rather two palaces than one. Its basement is perhaps, speaking without reference to the vast area in front of it, too high, and the intercolumniations too wide, for the order (Corinthian) employed; but it is easier to find fault than to do equally well; and we cannot leave the subject without a declaration that we never pass away from its beauties without a wish to return and contemplate their extreme elegance. They are to us of that class to which Cicero's expression may be well applied: "pernoctant nobiscum, peregrinantur." Gabriel died in 1742. Antoine, the architect of the Mint at Paris, was another of the choice spirits of the period: he continued the refined style whereof we are speaking; and though the age of Louis XV. was not destined to witness the erection of such stupendous edifices as that of Louis le Grand, it displayed a purer and far better taste. This architect was the first who employed in his country the Grecian Doric, which had then become known, though not perfectly, by the work of Le Roy. Antoine used it at *L'Hospice de la Charité;* and De Quincy cites it as a circumstance which called forth the approbation of people of taste, and observes that the attempt would have attracted more followers, if, instead of exciting the emulation of architects in the study of it and its judicious application to monuments, to which the character of the order is suitable, fashion had not applied it to the most vulgar and insignificant purposes. Antoine lived into the present century, having died in 1801, at the age of 68.

361. Louis XV., during a dangerous illness at Metz, is reported to have made a vow which led to the erection of the celebrated church of St. Geneviéve, or, as it has since been called, the Pantheon; the largest modern church in France, and second to none in simplicity,

elegance, and variety. Another cause may, however, with as much probability, be assigned; the inadequacy of accommodation for the religious wants of the population, and especially of that appertaining to the patroness Saint of Paris. Many projects had been presented

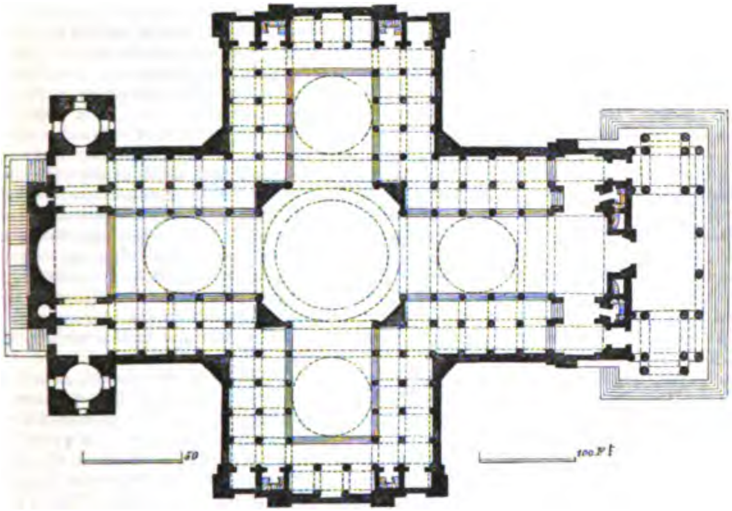


Fig. 177. PLAN OF PANTHEON, PARIS.

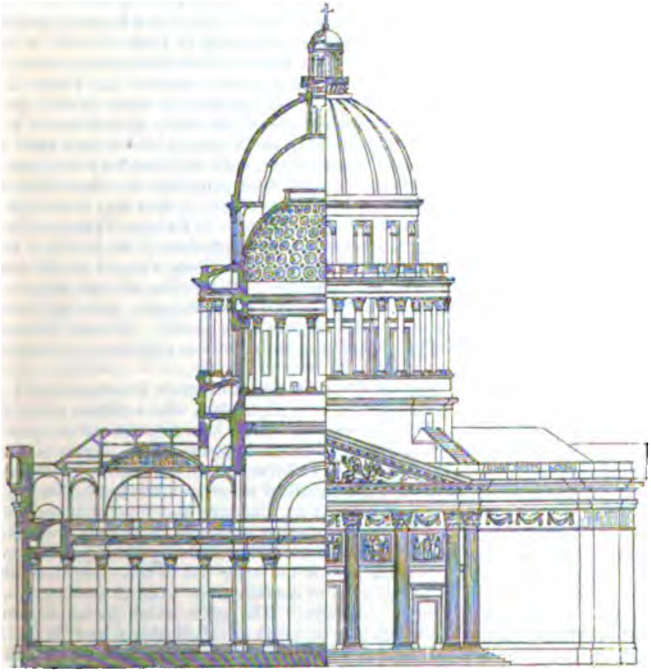


Fig. 178. ELEVATION AND SECTION OF PANTHEON, PARIS.

for the purpose, but that of Soufflot received the preference. This talented artist, who was born in 1713, at Irancy near Auxerre, after passing some time in Italy, had been settled at Lyons, and there met with considerable and deserved employment. In that city the great hospital had deservedly brought him into notice, for his knowledge in providing against the miseries of mankind, not less than had his beautiful theatre for providing for its pleasures. The plan (*fig.* 177.) of the Pantheon (so it is now usually called) is a species of Greek cross. The interior is separated into three very unequal parts by isolated columns, instead of the plans previously in use of arcades decorated with pilasters. It is, however, strictly, in its internal as well as external character, to be classed as belonging to the Venetian school. Its west front and transverse section are given in *fig.* 178. The light effect, which is so striking in the interior, produced by the employment of columns instead of the old system of arcades, is extremely pleasing, though, as has often been truly urged, they have no office to perform. Objections, moreover, have been taken to the wide intercolumniations of the portico, and to some other parts, which here it is unnecessary to particularise. It is, notwithstanding all that has been written against it, most certainly entitled to take the fourth place of the modern great churches in Europe; which are, Santa Maria del Fiore at Florence, St. Peter's at Rome, St. Paul's at London, and then the church in question. Its greatest fault is instability about the piers of the cupola,—the old fault, from which not one is altogether free, and one which gave Soufflot so much uneasiness that it is said to have hastened his death. This failure was afterwards rectified by his celebrated pupil Rondelet, who, with consummate skill, imparted perfect and lasting security to the edifice.

362. We ought perhaps before to have mentioned the name of Servandoni, as eminently influencing, in his day, the taste of Paris, which, as the world knows, is that of France. A Florentine by birth, and a scholar of the celebrated Pannini, he, in 1731, exhibited a model for the façade of St. Sulpice; and after a year's probation before the public, it was adopted. On an extended front of 196 ft. he succeeded in imparting to it, as a whole, an air of great majesty, and of giving to the church a porch of vast extent without injury to the general effect. Servandoni was very extensively employed: his style was that of the Venetian school; and his death occurred in 1766.

363. To write an history of the modern architecture of France, and at the same time to do its professors justice, would require a much larger volume than that under our pen: we profess to give no more than a bird's-eye view of it, so as to bring the reader generally acquainted with its progress; and it is not without much regret that we propose closing our account of it in the person of Jacques Gondouin, who died at Paris in 1818, at the age of eighty-one; an architect whose veneration for the works of Palladio was so unbounded, that for the study of them exclusively he performed a second journey into Italy: a strange infatuation in a man of great acquirements, if the opinions of some of our anonymous critics are of any value. When Gondouin was employed, the heavy style of Louis XIV. had passed away, and the suitable and elegant style of the Venetian school had been adopted. The pupils of Blondel, among whom he was eminent, were stimulated by the patronage of the whole capital; and even in the present day, so far capable are its inhabitants of appreciating the merits of an architect, regret as we may to record it, that it is from that circumstance alone likely to maintain its superiority over all others in Europe. The most celebrated work of Gondouin is the Ecole de Médecine, whose amphitheatre for lectures, capable of holding 1200 persons, is a model for all buildings of its class, without at all entering on the great merits of the other parts of the building. He was one of those upon whom the effects of the French Revolution fell with particular force, though, upon the re-establishment of order, he in some measure recovered his station in society. He was entrusted with the erection of the column in the Place Vendome, but merely as respected its preparation for the sculpture.

464. In Paris is to be found some of the most beautiful street architecture in Europe. That of Rome and Florence is certainly of a very high class, and exhibits some examples which will probably never be equalled. These, moreover, have associations attached to them which spread a charm over their existence of which it is not easy to divest one's self, and which, perhaps, contain some of the ingredients which enter into our high admiration of them. But, on a great and general scale, the most beautiful street architecture in Europe is to be found in Paris; and so great in this respect do we consider that city, that we are certain the education of an architect is far from complete if he be not intimately acquainted with the examples it affords. In that, as in most of the cities of Europe, the requirements of the shopkeeper interfere with the first principles of the art; but in this, less than others, the violation of the rules of sound building, so as to connect them with his accommodation, are less felt by the critical observer than elsewhere. The spirit which seems to actuate the French nation is to produce works which may properly be called *monumental;* in this country, the government has never applied itself to a single work worthy of that epithet. The principal care of an English minister seems to be that of keeping his place as long as the nation will endure him. Commerce and politics are the only subjects which such a personage

seems to think worthy his attention, and the sciences have only been patronised by the government in proportion to their bearing on those two absorbing points. But we shall perhaps revert to this in the following chapter.

Sect. XVIII.

GERMAN.

365. No country exhibits more early, beautiful, or interesting specimens of Romanesque and pointed architecture, than Germany. The Rhine, and the southern parts of it which were under the sway of the Romans, are those, as we have already observed, in which these are principally to be found. Their history, however, has, sufficiently for general purposes, been traced under the sections of Byzantine or Romanesque and Pointed Architecture. The revival of the arts in Italy, as it did in other nations, here equally brought in the styles of the Italian schools, which, as elsewhere throughout Europe, have lasted to the present period; and will certainly endure until some general change in the habits of its different nations renders necessary or justifies some other style as a worthy successor to them. On this to speculate were a waste of time; though there be some, and those men of talent, who contemplate a millennium of architecture, by making every thing in style dependent on the new materials (cast-iron for instance) which it is now the practice to employ, and often, it must be conceded, most usefully. Whilst the pointed style lasted in Europe, Italy was occasionally indebted to the Germans for an architect. Thus, notwithstanding the denial of Milizia, Lapo, a German architect, was employed in the early stages of construction of Santa Maria del Fiore; and it is well authenticated that Zamodia a German, Annex of Friburg, and Ulric of Ulm, were employed on the cathedral at Milan. Franchetti (*Storia e Descrizione del Duomo di Milano*, 4to. Milan, 1821) asserts, that the first of these was engaged on it about 1391, the period of the golden age of pointed architecture in Germany; and the reputation of the Germans in this respect was at that time so great, that John and Simon of Cologne were actually carried into Spain for the purpose of designing and carrying into execution the cathedral at Burgos. It is at this period difficult to assign the cause of the nation so completely dropping astern, to use a nautical phrase, in the fine arts, and more particularly architecture. It was most probably the result of their political condition, and the consequent relative position they occupied in the affairs of Europe. But, whatever the cause, it is, in fact, most certain, that from the revival of the arts in Italy until near the end of the 18th century, Germany furnishes the names of few, if any, architects who are known beyond the limits of the country. Italy during the time in question seems to have repaid the nation for the early assistance received from them. At Fulda and Vienna, Carlo Fontana was extensively engaged; Guarini on the church of Santa Anna at Prague; Scamozzi on the cathedral at Salzburg; Andrew Pozzo, who died at Vienna in 1709, was there employed on several of the churches: Martinelli of Lucca was another of the number that were solicited to decorate the country with their works. Fischers, indeed, was a native; but his works, and especially his palace at Schönbrun, begun in 1696 for the Emperor Joseph, though not altogether without merit, is but a repetition of the extravagances of the school of Borromini; and equally so was the palace built by the same artist for Prince Eugene at Vienna, in 1711. (*Essai d'Architecture Historique*, Leipsig, 1725.) Pietro Cart, who built the bridge at Nuremberg, Neuman, Bott, and Eosander of Prussia, are the only native architects of the period recorded by Milizia.

366. But it was not only from Italy that the Germans drew their architects: France contributed a supply to the country in the persons of Blondel, who was there much employed towards the end of the 17th century; Robert de Cotte and Boffrand in the first part of that following. It is therefore, from what has been stated, impossible to give any independent account of the architecture of Germany. The Germans had none. Whoso were their architects, they were the followers of a style which contemporaneously existed in France and Italy even down to the bizarreries of that which prevailed in the time of Louis XV.; and it is a very curious fact, that whilst Germany was seeking the aid of architects from France and Italy, England could boast of professors of the art whose fame will endure while printing remains to spread knowledge amongst mankind. During the last century, Germany appears to have risen in this respect from its slumber, and to have produced some men of considerable architectural abilities. Of these was Carl. Gotthard Langhans, who was born in 1732, and built the celebrated Brandenburg gate at Berlin, which, though formed much on the model of the Propylea at Athens, and therefore on the score of originality not entitled to that praise which has been so unsparingly exhausted upon it, proves that a vast change had begun in Germany as respected matters of taste in ar-

chitecture. Copies prove sad poverty of imagination on the part of the artist copying; and all, therefore, that can be said in favour of such an expedient as that under consideration is, that better forms being submitted in this example to the Germans, it created a dawn of taste to which they had long been strangers. The inaccurate work of Le Roy, which had preceded that of Stuart and Revett on the antiquities of Athens, was the means through which Langhans wrought and tried his successful experiment. In France, as we have already observed, Antoine had tried the employment of the Grecian Doric at Paris, but without the impression produced by Langhans. This architect died at Berlin in 1808, and is, perhaps, entitled to be considered as the father of good architecture in Germany, where he met the highest patronage and encouragement. Knoblesdorff, who died in 1753, had, it must be allowed, prepared in some measure the change which was effected; but neither he nor his successor are known in the world of art beyond the confines of their own country. The names of Boumann, Goutard, Naumann, and others of much merit, occur to us; but the examples which they have left are not of the class that justify specimens for presentation to the reader in a general work of this nature. None of them rise so high as to be put in competition with the examples of the French school; and the circumstance of the principal works of Germany at Munich, Berlin, &c. having been executed by artists still living, we feel precluded here from allusion to them; because, if we were to enter on an examination of them, we must detail their defects as well as their beauties. An extraordinary species of bigotry has laid hold on some in relation to them, which time will temper; and the world, as it always does, will ultimately come to a right judgment of the rank they are entitled to occupy as works of art. In the other branches the Germans are rising fast; but there is withal an affectation of the works of the middle ages in their productions, which, impressed as they are with great beauties, are not sufficiently pure to prognosticate the establishment of schools which will sweep all before them, as did those of Italy.

Sect. XIX.

SPAIN AND PORTUGAL.

367. What has been said in the preceding section on the architecture of Germany is equally applicable to that of Spain and Portugal, whose architects were educated, if not in the schools of Italy, yet on the principles that guided them. Still, the pre-eminence in architecture on the revival of the arts must be given to these countries over the contemporaneous buildings erected in Germany, and more especially to those of Spain. Under Ferdinand and Isabella, both greatly attached to the fine arts, the pointed style gave way to the architecture then in esteem in Italy; and Giovanni de Olotzaga, a native of Biscay, is, we believe, entitled to the merit of having first introduced it in the great college of Santa Croce at Valladolid, which was commenced in 1480, and finished in 1492. About the same period appeared Pietro de Gumiel, supposed to have been the architect of Santa Engracia at Saragossa; but known as the artist who designed the college of Alcala, a splendid building in a mixed and impure style. In this the orders were employed. The edifice consists of three courts: the first Doric, with an arcade and two orders above, in the lower whereof the Doric was repeated, and the upper was Ionic; the second court has thirty-two Composite columns, with arcades; and the third is designed with thirty-six Ionic columns, beyond which is the theatre. The church is of the Ionic order, and contains the monument of Cardinal Ximenes, the founder, considered one of the finest in Spain. The names of Giovanni, Alonso, and Fra Giovanni d'Escobado continue in their works the history of the art in Spain, wherein a style between the pointed and Italian prevailed during the greater part of the reign of Charles V. Giovanni Gil de Hontanon, at the end of the 15th century, appears in Spain as an architect of much celebrity. He made a design for the cathedral at Salamanca, which was submitted to the judgment of four of the then most eminent architects of the country,—Alonzo de Cobarrubias, the architect of the church at Toledo; Mastro Filippo of that of Seville; Giovanni di Badajos of that of Burgos; and Giovanni Balleso, by whom Hontanon's design was approved and commended. This church is 378 ft. long, and has a nave and two series of aisles on each side. The nave is 130 ft. high, and 50 ft. wide. Rodrigo Gil, son of the above-named architect, had the execution of this church, which commenced in 1513. It was probably this Rodrigo who, in 1525, erected the church of Segovia, very similar to that of Salamanca, except that it is more simple, and in a purer style. The cathedral of Segovia, equal in size and grandeur to those of Toledo and Seville, was, after 1577, carried on by Francesco de Campo Aguero, who died in 1660; to whom succeeded Biadero, who died in 1678. Respecting Hontanon, Don Ant. Ponz observes, in the 10th volume of his *Travels in Spain*, that he must have been a clever architect, and well acquainted with the Greek and

Roman styles, which in his time were beginning to revive; but that, like many other artists, he was obliged in some measure to humour the taste of those who employed him: he therefore adopted the Gothic style, without the ornaments and details. The efforts of the architects of this period were not confined altogether to church building; for in 1552 Pietro de Uria constructed a bridge at Almaraz over the Tagus, which may vie with the most extraordinary works of that class. Two large pointed arches form the bridge, which is 580 ft. long, 25 ft. wide, and 134 ft. high. The opening of one of the arches is 150 ft., that of the other 119 ft. The piers are lofty towers, that in the centre standing on a high rock. Another pier has a semicircular projection between the arches, forming a piazza at the top.

368. Alonzo de Cobarrubias, the architect of the church of Toledo, seems to have used in it a Gothic sort of style, though when he flourished the Roman orders had become known and used. This Alonzo was in considerable employ, as was his assistant, Diego Siloe, who built the church at Granada, with the monastery and church of San Girolamo in that city. This cathedral has a nave and two aisles; and in it the Corinthian order, though defective in height, is used. The cupola is well designed. Both Siloe and his master loaded their buildings with sculptures to excess, from a seeming notion that beauty and richness were the same or inseparable. Alonzo Berruguette was another architect of the 16th century who was deservedly employed. He went to Italy in 1500, there to pursue his studies in the arts of painting and sculpture as well as architecture, and was at Florence when Michael Angelo and Leonardo da Vinci exhibited their cartoons. He was the architect of Charles V.; and it is supposed that he designed the palace at Madrid, begun by Henry II., continued by Henry III., and splendidly rebuilt by Charles V., but no longer in existence. Berruguette erected the gate of San Martino, which is the principal one at Toledo. It is of the Doric order, with the royal arms on the exterior, and a statue of Santa Leocadia in the interior. There are great simplicity and elegance in the composition of this work. The palace of Alcala, the residence of the archbishop of Toledo, is attributed to him; a building not wanting in magnificence, though defective in its detail. A great portion of the cathedral of Cuença is said to be by Berruguette; but not the façade, which was erected in 1699 by Guiseppe Arroyo, and afterwards continued by Luigi Arriaga. There is considerable effect about the cloister, which is well and ingeniously decorated. This architect, it is thought, had some part in the Pardo, which was rebuilt in 1547; where are still allowed to remain,—notwithstanding the additions by Philip II. of the miserable eastern and western façades—the porticoes of Ionic columns, with their low stone arches. Though the windows are greatly too far apart, and too small in the lower story, the stairs difficult of ascent, yet, upon the whole, the edifice is not ill arranged or executed. At the period whereof we here speak there was a prodigious passion among the Spaniards for large screens and altars in the churches; in these the taste of Berruguette was most conspicuous. In the use of the orders, which he fully understood, he was remarkably fond of employing them over one another. The cathedral at Seville was principally rebuilt by Ferdinando Ruiz, who was much engaged in the city, and especially on enlarging or raising the well-known tower called the Giralda. This singular edifice was begun in the 11th century, the original idea of it being given by the architect Geber, a native of Seville, to whom the invention of algebra is attributed; and also the design of two other similar towers, one in Morocco, and the other at Rabata. The tower of which we are now speaking was at first 250 ft. high, and 50 ft. wide, and was without diminution as it rose. The walls are 8 ft. thick of squared stones from the level of the pavement; the rest for 87 ft. is of brick. In the centre of this tower is a smaller one, the interval between the two towers being 23 ft., which serves for the ascent; one so convenient that two persons can mount it on horseback. The centre tower does not diminish; but as the edifice rises in height the walls gather over, so as to allow the passage of only one person. Upon the Moors of Seville negotiating their surrender, one of the conditions of it was, that this tower should not be destroyed; to which Don Alphonso, the eldest son of the king, answered, that if a portion of it were touched, not a man in Seville should survive. In the earthquake of 1395 it was partially injured, and remained in the state of misfortune that then occurred until 1568, when, by the authorities, Ferdinando Ruiz received the commission to raise it 100 ft. higher. This height he divided into three parts, crowning it with a small cupola or lantern: the first division of his addition is of equal thickness with the tower on a plinth, whence six pilasters rise on each façade, between which are five windows, over which is an entablature surmounted by balustrades; the second division is lower, with the same ornament; and the third is octagonal with pilasters, over which the cupola rises, crowned with a bronze statue of Faith, vulgarly called "La Giralda." Ruiz by this work augmented his fame; and notwithstanding the earthquakes which have since occurred, he has been fortunate enough to preserve it. We have, however, to apologise to our readers for this, which is anecdote, and not quite in order to be placed here, because partly connected with a period we have long since left. Pictorially speaking, the tower of the Giralda is a splendid object, and the

apology was, perhaps, unnecessary. The age of Charles V. in Spain was Augustan for its architecture. By his mandate the palace was raised at Granada, a work of Machuca, another architect of this period. The principal façade is rustic, with three large gates, and eight Doric columns on pedestals sculptured with historical bassi-rilievi. The second story is Ionic with eight columns, over which are pilasters. The internal vestibule is on a circular plan, with a portico and gallery on columns of the same order. Milizia, from whom we have extracted all our notices on the architecture of Spain in this age, regrets that the arches spring from the columns. Though we cannot commend such a practice, we should be sorry, in certain cases, to see a veto put upon it; because the practice is occasionally compatible with fine effect.

369. Towards the end of the sixteenth century appears in Spain an artist, by name Domenico Testocopoli, by birth a Grecian, and a disciple of Tiziano Vecelli. He became, under his master, a good painter; but is known in Spain rather as a celebrated architect in his day. At Madrid, and in Toledo, he executed many works of merit; but his grand work was the church and monastery of the Bernardine monks of San Dominico di Silos, in which he employed his talents in architecture, painting, and sculpture, the whole being from his hand.

370. Garzia d'Emere and Bartolomeo di Bustamente, the latter especially, would require an extended notice in the history of the art in Spain, if our limits permitted us to enter on their merits. The latter was the architect of the hospital of San Giovanni Battista, founded by its archbishop in 1545, near Toledo. We should continue the account if works existed from which a feature different from the contemporaneous works in the rest of Europe could be extracted; but the fact is, that the progress of the art has already been told in other countries, and its success in Spain would be but a repetition in minor degree of what has already been said. Still we consider some notice must be taken of Giovanbatista of Toledo, who died in 1567, an architect and sculptor of surpassing merit; and as he was the architect who gave the designs for the façade of the Escurial, we shall not apologise for transcribing the account of him given by Milizia.

371. Having studied at Rome, he was invited to Naples by Don Pietro di Toledo, then viceroy there, who employed him as architect to the Emperor Charles V. in many important works in that city, whence he was called by Philip II. to become architect of all the royal works in Spain, and especially of the Escurial, which that monarch was anxious to erect in the most magnificent style. For this purpose he left Naples, and in 1563 commenced, upon his own design, the Escurial, which he continued to superintend till his death in 1567. In this great undertaking he was succeeded by Giovanni d'Herrera, his pupil, who finished it. Those, therefore, says the author whom we quote, that attribute this work to Luigi de Foix, to Bramante, to Vignola, and other architects who may have given designs for it, are unacquainted with the subject. The wonders related of the Escurial, as to the number of its doors and windows, are not tales to be here recounted; and the attempt, indeed, at exaggeration is vastly silly, because it is on so grand a scale that the simple truth imparts quite sufficient knowledge for conveying an idea of its splendour. The motives of Philip II. in founding this structure were twofold, — first, the injunction of his predecessor Charles V., who was desirous of constructing a tomb for the royal family of Spain; and secondly, of erecting an edifice of colossal dimensions to commemorate the famous victory of S. Quintin, achieved on the festival of San Lorenzo, the saint to whose interposition the king attributed his success. The situation chosen to receive it was beautiful. It is at the distance of a few miles from Madrid, at the foot of the Carpentani mountains, by which the two Castiles are divided. The plan of the edifice is said to resemble a gridiron, the instrument of martyrdom of Saint Lawrence, of which the handle is the projection in the eastern façade; we confess, however, we have some difficulty in tracing the resemblance. It is divided internally into fifteen courts, varying considerably in size; many of them are decorated with porticoes and galleries, and contain in all upwards of eighty fountains. The materials are granite very well wrought; the roofs partly covered with lead and partly with slate. The cupola of the church is stone. The four angles of the main plan are distinguished by towers rising four stories, besides those in the roofs, above the general fronts; besides which there are four others flanking the cupola. Parts of the building are in much better taste than others; but such an enormous pile of building cannot be otherwise than imposing, more especially, too, if there be anything like symmetry and regularity in the parts. Towards the west the principal façade is 740 feet long and 60 feet in height. The towers at the angles just mentioned rise to the height of 200 feet. This façade, like the others, has five stories of windows, which necessarily of themselves, from the way in which they are arranged, have the effect of cutting it up into minute divisions. The central compartment of it is 140 feet in length, and consists of two orders of half columns; the lower has eight semi-columns, which are Doric, standing on a plinth, and in the central intercolumniation is the door; the other intercolumniations are filled in with niches and windows in three stories. The upper order is of four Ionic columns on pedestals, which are surmounted by a pediment. This upper

order has two stories of niches in its intercolumniations, in the upper central one whereof is placed the statue of St. Lawrence. The two minor doors in this façade are also made features in the design. The façade towards the east has the projecting handle of the gridiron to which we have alluded, in which part is contained the palace; and westward of it the great chapel or church, with its cupola rising above the mass, to complete the composition. Towards the south the length is 580 ft., similar to the length on the north. On entering from the central gate of the western façade, the monastery is divided from the college by a large vestibule, from which three large arched openings lead into the king's court: this is 230 ft. long, and 136 ft. wide, surrounded by buildings of five stories, and ornamented with pilasters. At the eastern end of this court is the entrance to the church, over whose vestibule or pronaos are the libraries. To it a flight of seven steps crosses the whole width of the court; and from the landing rises a Doric arcaded porch of five openings, three whereof belong to the central compartment and lead to the church, the other two leading to the monastery and the college. Behind the porch the façade of the church rises, and is flanked by two towers, which respectively belong to the monastery and college, and are ornamented above the general height of the buildings of the court with two orders of pilasters, being terminated by small cupolas. The interior of the church is Doric, and is in plan a Greek cross. The nave is 53 ft. and the aisles are 30 ft. wide. Its whole length is 364 ft., its width 230, and height 170. From the intersection of the nave and transepts the cupola rises, 66 ft. in diameter, and 330 ft. in height from the pavement to the cross. Its exterior is composed with a square *tambour* or drum, if it may be so called, from which the order rises. The choir is only 30 ft. high, and its length but 60 ft. In point of taste and dimensions, the church is inferior to several in other parts of Europe. The presbytery, we should have stated, is raised, so as to form almost another church, and seemingly without relation to the principal one. The staircase which leads to the Pantheon, and which possesses considerable magnificence, is placed between the church and the antesacristy: we are not aware why this name has been given to the sepulchre of the kings of Spain. It is nearly under the high altar. The chamber appropriated to the reception of the kings is 36 ft. diameter, and 38 ft. in height, richly encrusted with various marbles and metals, and ornamented with sixteen double Corinthian pilasters on pedestals, arranged octagonally; and between them are recesses, with the sarcophagi, amounting to twenty-six, that is, four in each of six sides, and two over the entrance which faces the altar of the Resurrection. This is a fair specimen of the style which prevailed in Spain under the reigns of Philip IV. and Charles II. The college, the seminary, and the royal palace occupy the rest of the building. In 1773, many additions were made to the buildings about the Escurial for the Infants Don Antonio and Don Gabriele, by Villaneuva, an Italian architect, and by them the palace was much improved. Giovanni d'Herrera, who died in 1597, besides his employment at the building just described, contributed greatly to the advancement of the art by the execution of the many commissions with which he was entrusted. The bridge of Segovia, at Madrid, is by him; as is the royal pleasure-house at Aranjuez, begun under Philip II. and finished by Charles III., — a work which, though far from pure, exhibits great architectural ability. His successor at the Escurial was Francesco de Mora, by whom, at Madrid, is the Palace de los Consejos, the most splendid edifice which that capital can boast. Instead of a central doorway, it has two at its flanks, of the Doric order, with appropriate decorations. In the beginning of the seventeenth century, the great square of Madrid was erected after the designs of Giovanni Gomez de Mora, and is admirable for its grandeur and symmetry. This architect built at Alcala the church and college of the Jesuits, which, Milizia says, is a magnificent and well-proportioned edifice. It is of two orders, and the material employed in the façade is granite. The royal convent of the Augustins, at Madrid, is also attributed to him.

372. In the beginning of the eighteenth century, Filippo Ivara, a native of Messina, had very great employ, we might almost say throughout Europe. He became the pupil of Fontana, and afterwards, on his visiting Spain, seems to have established a school there. He built the façade of the royal palace of St. Ildefonso, looking towards the gardens. Ivara died in 1735, at Madrid, whither he had been invited by Philip V. to rebuild the palace, which had been consumed by fire. The work was afterwards intrusted to Sacchetti, a pupil of Ivara. It is on a very large scale, and was most solidly constructed.

373. We have thought it necessary to give the above succinct account of the architecture of Spain, which did not, however, produce, after the revival of the arts in Europe, any works, except in respect of dimensions, comparable with those of Italy. The abuses in them are almost universally carried to an extent scarcely credible; it is, therefore, useless to refer the reader or student to them as models. It almost seems as if from Italy pure architecture had not had time to spread itself before it became tinctured with the corruptions of Borromini; which, not only in Spain and Portugal, but throughout Germany, and even France, were diffused with incredible rapidity.

Sect. XX.

RUSSIAN ARCHITECTURE.

374. We scarcely know whether we are justified in making a short section with this heading, inasmuch as there is not known to us, up to the end of the eighteenth century, the name of a single Russian architect. English, French, Italian, and German artists have been employed in the decoration of the city of Petersburg, though we believe that the nation is now beginning to produce persons capable of conducting their public works. Russia has received all its improvement from abroad, and has used every exertion to communicate it to an uncivilised people.

375. The ecclesiastical architecture of Russia is of course coeval with the introduction of Christianity into the country, which was not earlier than the time of Vladimir the Great, although the Princess Olga had been baptized at Constantinople as early as the year 964. Vladimir, to display his zeal in behalf of Christianity, had a church, supposed to be the first built by him, erected at Cherson; a year after which the church of St. Basil, which, as well as the first named, was of timber, was erected under his command. This prince also built a church at Kief, where, it is said, there were already at the time 500 churches. After Vladimir, Prince Yaroslaf appears to have bestowed great attention on the erection of ecclesiastical edifices. At Kief he founded a church, dedicated to St. Sophia, and at Novogorod another to the same saint: these partly exist in the present day. By him also were reared the convents of St. George and St. Irene. The celebrated convent of Petchorsky, at Kief, was erected in 1075, subsequent to which period the Russian metropolitans have continued subject to those of Constantinople. Between this last capital and Kief the bonds of amity of their rulers were drawn closer by many intermarriages; but in the year 1124 a fire desolated the latter city, which must have risen into great importance, inasmuch as 600 churches and monasteries were destroyed in the conflagration. Afterwards, again, in the civil war under Yisaslaf, Kief was taken and fired; a calamity to which it was again subject at the same period that Constantinople was taken by the Venetians. After this Kief never again recovered its ancient magnificence. In 1154, at which period Moscow is first mentioned in history, it was but an insignificant village. It received great additions under Daniel of Moscow; and in 1304, under John Danielowitz, it became the capital of the empire. On the 4th of August, 1326, the first stone was laid of a church in the Kremlin there in honour of the Assumption of the Virgin. The palace of the Kremlin was a timber structure until the reign of Demetri Donskoi, when it was reconstructed of stone. On the capture of Constantinople by Mahomet the Second, the Russian church ceased to be dependent on that of Constantinople. The palace of the Kremlin, known by the name of the granite palace, rose in 1487; and, in twelve years afterwards, the Belvedere palace was raised. Ivan IV., whose sway was of extended duration, was a great patron of the arts; his decease took place circa 1584. He renewed the laws relative to the paintings in the new churches, whence arises their so close resemblance to one another that it is difficult to judge of the epochs of their execution. The celebrated clock tower Ivan Valiki, at the Kremlin, was erected by the Czar Boris, in 1600, at which time Moscow contained 400 churches, whereof 35 stood in the Kremlin alone. After the time of Peter the Great, a change of style was introduced.

376. The Church of the Assumption above mentioned, as respects the plan, is an oblong square divided; the vaulting whereof is supported by six columns in the interior. Though at the first glance it be not perceived, the arrangement of the cupolas soon points to the form of a Greek cross. In the earlier churches the plan was a square, with a porch in front of it; but, in the Church of the Assumption, the porch is a portion of the church, the arches of the cupolas being placed in the same way as if the church were of the ancient form. The six columns just mentioned divide the church into four parts, — from east to west, and then from north to south. At the eastern sides are three apsides, divided by the width of a column, the middle one being of larger dimensions than the other two; an arrangement which prevails in most of the Greek churches. The apsides contain altars, which are frequent, except in the small chapels. The altar in the Greek church is not exposed to public view; it is concealed or covered by the iconostasis (image-bearer), a very large screen, which, from occupying the whole width of the church, divides it into two parts. This screen has a central principal and two side smaller doors; behind which latter, on each side, stands a second and smaller iconostasis, of the width only of the smaller apsis, but whose plan with three doors and an altar behind is similar to the great one. This was the distribution in the early churches; but, in the more modern ones, there are, at nearly the extremity of the edifice, three distinct iconostases. The place for the choristers is on each side in front of the iconostasis, between its principal and side doors. The principal cupola rises in front of the iconostasis; and, in cathedral churches, at the foot of the apsis on the left a canopy is placed for the emperor, opposite whereto is one for the metropolitan.

There is generally one principal and four subordinate cupolas round it, which stand on the four feet of the Greek cross. The iconostasis is a principal object in every church. It is usually in four or five horizontal compartments, each containing an unequal number of pictures of saints painted on tablets or long square panels, whose places are fixed with great precision. In the first story, if we may so call it, are the three doors; the centre one, being in two foldings, is decorated with the subject of the Annunciation, accompanied with the heads of the four Evangelists or their emblems. To the right of the door is a picture of Christ, and of the Madonna on the left. To the right of the Christ is the saint or festival of the church, after which the doors are inserted. Above the doors, on the left hand, is placed a Greek cross; on the right hand the cross of Moses, — as symbols of the Old and New Testaments. The paintings are all on a ground of gold. In the middle of the second story is Christ on a throne; on the right Saint John the Baptist; on the left the Madonna without Child; then, on each side, two archangels and six apostles. In the third story or horizontal compartment, the Madonna is introduced with the Infant on her knees, surrounded on each side by the prophets. In the fourth story is painted God the Father on a throne, with the Infant Jesus, surrounded on each side by patriarchs of the church. Occasionally a fifth story appears, upon which is painted the history or Passion of our Saviour. Paintings on a gold ground abound in the other parts of the church. The exteriors of these churches are extremely simple; cornices or other horizontal crownings are not to found, but the coverings follow the cylindrical forms of the arches to which they are the extradoses, and are variously painted. The Russian churches built in the eleventh century, which from the number of their cupolas resemble, and indeed were imitated from those of the East, give a peculiar effect to the architecture. The forms of these cupolas are varied, but they generally stand on an octagonal *tambour;* some are hemispherical, others in curves of contrary flexure, and a number of other figures.

377. The type of the Russian church, which is on plan a Greek cross, is to be found in Santa Sophia at Constantinople. After the disputes between the Iconoclasts and Iconolaters, which, at the close of the seventh century, ended in the separation of the Eastern and Western churches, sculpture of statues disappeared from the Greek church, statues of angels excepted. Again, at this period, the altars on the side of the principal one were established, not, as in the Catholic churches, at the extremities of the transepts; their place is always in a niche or apsis. This arrangement is found in the churches of the eleventh, twelfth, and thirteenth centuries, at Bari, Trani, Malfetta, Otranto, &c., while the Greek worship existed; and a similar disposition is even seen at Palermo and other places where the worship has been Catholic. In the Catholic churches a sacristy, for the use of the priests in robing, &c., is always provided on the side of the church; in the Greek church, however, the priests robe themselves behind the iconostasis on the left of the altar, another altar being placed on the right for the consecration of the elements; and this arrangement exists in the present day. The Greek church has no gynæceum, or separate place for the women. — For the above we are indebted to the researches of M. Hallmann, an ingenious architect of Hanover.

378. It is in Saint Petersburg principally that we are to look for edifices which deserve mention. The foundation of the city was laid in 1703, by the Czar Peter, when he constructed a fort on an island in the Neva for defence against the Swedes. Buildings, both public and private, were soon erected; and the nobility and merchants being induced to settle there, the place quickly assumed the appearance of a considerable city. In the reigns of Catherine the Second and Alexander it reached a degree of great magnificence, from which it has not declined, but has rather advanced. Magnitude, rather than beauty of form, marks the public buildings of the city. The church of our Lady of Kevan is of great dimensions: for which, and its fifty-six granite columns with bronze capitals, it has obtained more celebrity than it will acquire for the beauty of its composition. Some of the palaces in the city are of colossal dimensions; that of Michailoff, built by Paul, is said to have cost ten millions of rubles. It was under the reign of Peter the Great that the great change took place in the national character of Russian church architecture by the introduction of the classical orders. The bulbous cupola, though at this period not entirely laid aside, fell into comparative disuse, being replaced by a green painted dome of which the Italian form was the model. The tasteless custom of painting the exteriors of buildings with bright and incongruous colours was retained; and, though well enough suited to the barbaric structures of the Muscovite czars, it ill accorded with the purer style of Italy. It is unnecessary further to detain the reader by any observations on the churches of the modern capital. In point of style or of history, they possess little or no interest for an English reader. To those who wish to become better acquainted with the architecture of Russia, we recommend a reference to Geissler's *Tableaux Pittoresques des Mœurs, &c. des Russes, Tartares, Mongoles, et autres Nations de l'Empire Russe.*

CHAP. III.

ARCHITECTURE OF BRITAIN.

Sect. I.

EARLY HOUSES AND ARCHITECTURE OF THE BRITONS.

379. On the invasion of Britain by Julius Cæsar, in the year *55* B. C., the inhabitants dwelt in houses resembling those of Gaul; and in Kent, and other southern parts of the island, their houses were more substantial and convenient than those in the north. Caves or earth houses seem to have been their original shelter; to which had preceded the wicker enclosure, whose sides were incrusted with clay. These were thatched with straw. The wooden houses of the ancient Gauls and Britons were circular, with high tapering roofs, at whose summit was an aperture for the admission of light and emission of smoke. These, where the edifices were grander than ordinary, were placed upon foundations of stone. There is no instruction to be derived from pursuing this subject further. That the arts at the period in question scarcely existed, is quite certain; and Caractacus may, when carried prisoner to Rome, have well expressed surprise that the Romans, who had such magnificent palaces of their own, should envy the wretched cabins of the Britons.

380. If the Britons were so uninformed in architecture as to be satisfied with such structures for their dwellings as we have named, it will hardly be contended that they were the builders of so stupendous a fabric as Stonehenge. On this subject we have already stated our opinion in Chap. II. From the distant period at which we believe this and similar edifices to have been erected up to that of which we are speaking many centuries must have elapsed, during which the mechanical knowledge which was employed in their erection might have been lost, and indeed must have been, from the condition of the inhabitants, of which mention has been made.

381. The Romans, after their invasion of the island, soon formed settlements and planted colonies; and it is not difficult to imagine the change which took place in its architecture. The first Roman colony was at Camalodunum. This, when it was afterwards destroyed by the Britons in the great revolt under Boadicea, appears to have been a large and well-built town, adorned with statues, temples, theatres, and other public edifices. (*Tacit. Annal.* lib. xiv. c. 32.) In the account given of the prodigies said to have happened at this place, and to have announced its approaching fall, it is mentioned that the statue of Victory fell down without any visible violence; in the hall of public business, the confused murmurs of strangers were perceived, and dismal howlings were heard in the theatre. At Camalodunum the temple of Claudius was large enough to contain the whole garrison, who, after the destruction of the town, took refuge in it; and so strong was it, that they were enabled to hold out therein against the whole British army for a period of two days. London, however, exhibited a more striking example of the rapid progress of Roman architecture in Britain. At the time of the first Roman invasion it was little more than a British town or enclosed forest; and there seems to be ground for supposing that at the time of the second invasion, under Claudius, it was not much improved. But when, about sixteen years afterwards, it came into the possession of the Romans, it became a rich, populous, and beautiful city. Not only did the Romans raise a vast number of solid and magnificent structures for their own accommodation, but they taught the arts to the Britons, and thus civilised them. Agricola, of all the Roman governors, took means for that purpose. That they might become less and less attached to a roaming and unsettled life, and accustomed to a more agreeable mode of living, he took all opportunities of rendering them assistance in erecting houses and temples, and other public buildings. He did all in his power to excite an emulation amongst them; so that at last they were not content without structures for ornament and pleasure, such as baths, porticoes, galleries, banqueting houses, &c. From this time (A. D. 80) up "to the middle of the fourth century," says Henry (*Hist. of England*), "architecture, and all the arts immediately connected with it, greatly flourished in this island; and the same taste for erecting solid, convenient, and beautiful buildings which had long prevailed in Italy, was introduced into Britain. Every Roman colony and free city (of which there was a great number in this country) was a little Rome, encompassed with strong walls, adorned with temples, palaces, courts, halls, basilicæ, baths, markets, aqueducts, and many other fine buildings both for use and ornament The country every where abounded with well-built villages, towns, forts, and stations; and the whole was defended by that high and strong wall, with its many towers and castles, which reached from the mouth of the river Tyne on the east to the Solway Firth on the west.

This spirit of building, which was introduced and encouraged by the Romans, so much improved the taste and increased the number of the British builders, that in the third century this island was famous for the great number and excellence of its architects and artificers. When the Emperor Constantius, father of Constantine the Great, rebuilt the city of Autun in Gaul, A. D. 296, he was chiefly furnished with workmen from Britain, which (says Eumenius) very much abounded with the best artificers. It was about the end of the third century that in Britain, as well as all the other provinces of the Western empire, architecture began to decline. It may have been that the building of Constantinople drew off the best artists; or that the time left for the peaceful culture of the arts may have been broken in upon by the irruptions of invaders from the north. According to the Venerable Bede (*Hist. Eccles.*, lib. i. c. 12.), the Britons had become so ignorant of the art before the final departure of the Romans that they, from want of masons, repaired the wall between the Forth and Clyde with sods instead of stone. Henry observes, however, on this, that "we cannot lay much stress on this testimony; because it does not refer to the provincial Britons, but to those who lived beyond the Wall of Severus, where the Roman arts never much prevailed; and because the true reason of their repairing that wall with turf, and not with stone, was that it had been originally built in that manner. Besides, we are told by the same writer, in the same place, that the provincial Britons, some time after this, with the assistance of one Roman legion, built a wall of solid stone, 8 ft. thick and 12 ft. high, from sea to sea."

382. The departure of the Romans, and that of the fine arts which they had introduced, were occurrences of almost the same date. We must, however, recollect that architecture was beginning to decline at Rome itself before the departure in question. The inhabitants of the country who remained after the Romans were gone had not the skill nor courage to defend the works with which the Romans had provided them; and their towns and cities, therefore, were seized by invaders, who plundered and destroyed them, throwing down the noble structures with which the art and industry of the Romans had adorned the country. The vestiges of Roman architecture still remaining in Britain are pretty numerous; but scarcely any of them are of sufficient interest to be considered as studies of Roman architecture. Even in its best days, nobody would study the works of art in the colonies in preference to those in the parent state. We have here (*fig.* 179.) inserted a representation of a small portion of the Roman wall at Leicester, as an example of the construction. Temples, baths, and villas of the time have, moreover, been brought to light not unfrequently.

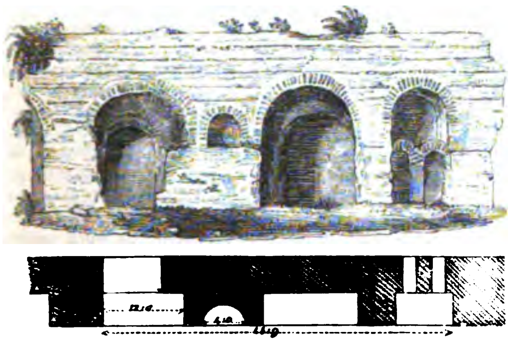


Fig. 179. ROMAN WALL, LEICESTER.

383. The arrival of the Saxons in this country, A. D. 449, soon extinguished the very little that remained of the arts in the island. This people were totally ignorant of art; like the other nations of Germany, they had been accustomed to live in wretched hovels formed out of the earth, or built of wood, and covered with reeds, straw, or the branches of trees. It was not, indeed, until 200 years after their arrival that stone was employed by them for their buildings. Their cathedrals were built of timber. The Venerable Bede says there was a time when not a stone church existed in all the land; the custom being to build them of wood. Finan, the second bishop of Lindisfarne, or Holy Island, built a church in that island, A. D. 652, for a cathedral, which yet was not of stone, but of wood, and covered with reeds; and so it continued till Eadbert, the successor of St. Cuthbert, and seventh bishop of Lindisfarne, took away the reeds, and covered it all over, both roof and walls, with sheets of lead. Of similar materials was the original cathedral at York, a church of stone being a very rare production, and usually dignified with some special historical record. Bede, for instance, says of Paulinus, the first bishop of York, that he built a church of stone in the city of Lincoln, whose walls were standing when he wrote, though the roof had fallen down. Scotland, at the beginning of the eighth century, does not seem to have had a single church of stone. Naitan, king of the Picts, in his letter to Ceolfred, abbot of Weremouth, A. D. 710, intreats that some masons may be sent him to build a church of stone in his kingdom, in imitation of the Romans.

384. We here think it necessary to notice that we have thought proper, under this chapter, to preserve the periods, or rather styles of the periods of architecture, according to their ordinary arrangement in English works, namely, the Anglo-Saxon and Norman, in distinct sections. It is a matter of little importance to the reader how he acquires his knowledge, so that his author do not unnecessarily prolong the acquisition of it. Though, therefore, the Anglo-Saxon and Norman architecture are neither of them any thing more than Romanesque or Byzantine, to which we have appropriated rather a long section, we have here separated them into two distinct periods.

385. About the end of the seventh century masonry was once more, as well as some other arts connected with it, restored to England, by the exertions of Wilfrid, bishop of York, and afterwards of Hexham, and of Benedict Biscop, the founder of the abbey of Weremouth. The former, who was an indefatigable builder, and one of the most munificent prelates of the seventh century, erected edifices, which were the admiration of the age, at Ripon, York, and Hexham. The cathedral of the latter place obtained great celebrity. Eddius, speaking of it (*Vita Wilfridi*), says, that Wilfrid, having obtained a plot of ground at the place from Queen Etheldreda, he there founded a very magnificent church, and dedicated it to the blessed apostle St. Andrew. The plan of this holy structure appears to have been inspired by the Spirit of God; a genius, therefore, superior to mine is wanting to describe it properly. Large and strong were the subterraneous buildings, and constructed of the finest polished stones. How magnificent is the superstructure, with its lofty roof resting on many pillars, its long and lofty walls, its sublime towers, and winding stairs! To sum all up, there is not on this side of the Alps so great and beautiful a work. Biscop was a zealous cotemporary and companion of Wilfrid, and had also a great love for the arts. He travelled into Italy no less than six times, chiefly for the purpose of collecting books and works of art, and of endeavouring to induce workmen to come over to England. An estate of some extent having been obtained by him from Ecgfrid, king of Northumberland, near the mouth of the river Were, he founded a monastery there in 674. Relative to this monastery of Weremouth, thus writes Bede: — "About a year after laying the foundations, Benedict passed over into France, and there collected a number of masons, whom he brought over with him to build the church of his monastery of stone, *after the Roman manner*, whereof he was a vast admirer. Such was his love for the apostle Peter, to whom the church was to be dedicated, that he stimulated the workmen so as to have mass celebrated in it but a little more than a year from its foundation. When the work was well advanced, he sent agents into France for the purpose of procuring, if possible, glass manufacturers, who at that time were not to be found in England, and of bringing them over to glaze the windows of his monastery and church. His agents were successful, having induced several artisans to accompany them. These not only executed the work assigned to them by Benedict, but gave instructions to the English in the art of making glass for windows, lamps, and other uses."

386. The Bishop Wilfrid, as we learn from William of Malmesbury, with the assistance of the artificers that had been brought over, effected great reparations in the cathedral at York, which was in a decayed and ruinous state. He restored the roof, and covered it with lead, cleansed and whited the walls, and put glass into the windows; for, before he had introduced the glass makers, the windows of private dwellings as well as churches were filled with linen cloth, or with wooden lattices. It will be observed that the improvements we here mention were introduced by the bishops Wilfrid and Biscop towards the end of the seventh century; but, from our ancient historians, it would appear that, in the eighth and ninth centuries, stone buildings were rarely met with, and, when erected, were objects of great admiration. The historian Henry observes, that "when Alfred, towards the end of the ninth century, formed the design of rebuilding his ruined cities, churches, and monasteries, and of adorning his buildings with more magnificent structures, he was obliged to bring many of his artificers from foreign countries. Of these (as we are told by his friend Aperius) he had an almost innumerable multitude, collected from different nations; many of them the most excellent in their several arts. Nor is it the least praise of this illustrious prince, that he was the greatest builder and the best architect of the age in which he flourished." His historian, who was an eyewitness of his works, speaks in the following strain of admiration of the number of his buildings, "What shall I say of the towns and cities which he repaired, and of others which he built from the foundation?" Henry continues, — "Some of his buildings were also magnificent for that age, and of a new and singular construction; particularly the monastery of Æthelingay. The church, however, was built only of wood; and it seems probable that Alfred's buildings were, in general, more remarkable for their number and utility than for their grandeur; for there is sufficient evidence that, long after his time, almost all the houses in England, and the far greatest part of the monasteries and churches, were very mean buildings, constructed of wood and covered with thatch. Edgar the Peaceable, who flourished after the middle of the tenth century, observed (see *William Malms.* lib. ii. p. 32.), that, at his accession to the throne, all the monasteries of England were in a ruinous condition, and consisted only

of rotten boards." The taste, however, of the Anglo-Saxons was not indulged in magnificent buildings; and the incursions of the Danes, who destroyed wherever they came, together with the unsettled state of the country, may account for their revenues being expended on mean and inconvenient houses.

387. Under the circumstances mentioned, it may be safely inferred that the art was not in a very flourishing state in the other parts of the island. Indeed, the ancient Britons, after retiring to the mountains of Wales, appear to have lost it altogether; and, as the Honourable Daines Barrington (*Archæologia*) has thought, it is very probable that few, if any, stone buildings existed in Wales previous to the time of Edward I. The chief palace, called the *White Palace*, of the kings of Wales, was constructed with white wands, whose bark was peeled off, whence its name was derived; and the price or penalty, by the laws of the country, for destroying the king's hall or palace, with its adjacent dormitory, kitchen, chapel, granary, bakehouse, storehouse, stable, and doghouse, was five pounds and eighty pence, equal, in quantity of silver, to sixteen pounds of our money, or 160*l*. The castles appear also to have been built of timber; for the vassals, upon whom fell the labour of building them, were required to bring with them no other tool than an axe.

388. Neither do the arts of building appear to have been better understood in Scotland at the former part of the period whereof we are speaking. The church built at Lindisfarne by its second bishop, Finan, in 652, was of wood, —*more Scotorum;* and it has already been mentioned that, for the stone church which Naitan, king of the Picts, built in 710, he was under the necessity of procuring his masons from Northumberland. In Scotland, there are still to be seen some stone buildings of very high antiquity, which Dr. Henry seems inclined to attribute to this period; we, however, are inclined to place them in an age far anterior, later (but not much so) than Stonehenge. We have never seen them, and therefore form our opinion from the description given in Gordon's *Itinerarium Septentrionale*. These buildings are all circular, though of two different kinds, so different from each other that they seem to be the works of different ages and of different nations. The four principal ones are in a valley, called Glenbeg. Of a different period, too, we consider the circular towers which are found as well in Scotland as in Ireland. It is true that in both countries these are found in the neighbourhood of churches; but that does not the more convince us that they were connected with them.

389. Ducarel, in his *Norman Antiquities*, enumerates some of the churches in England which belong to the ages anterior to the Norman conquest. Among them are those of Stukely in Buckinghamshire, Barfreston (*fig.* 180.) in Kent, and Avington in Berkshire. Other examples exist in Waltham Abbey; the transept arches at Southwell, Nottinghamshire; the nave of the abbey church of St. Alban's, Herts; the nave of St. Frideswide, Oxford, &c. &c. The Anglo-Saxon æra, though it, perhaps, properly comprised the time between A. D. 600 to A. D. 1066; that is, from the conversion of the Saxons to the Norman conquest, is not known with any thing approaching to certainty, from the reign of Edgar in 980 to the last-named event; immediately previous to which Edward the Confessor had, during his lifetime, completed Westminster Abbey in a style then prevalent in Normandy, and with a magnificence far exceeding any other then extant. No less than eighteen of the larger monasteries, all of them Benedictine, had been founded by the Saxon kings in

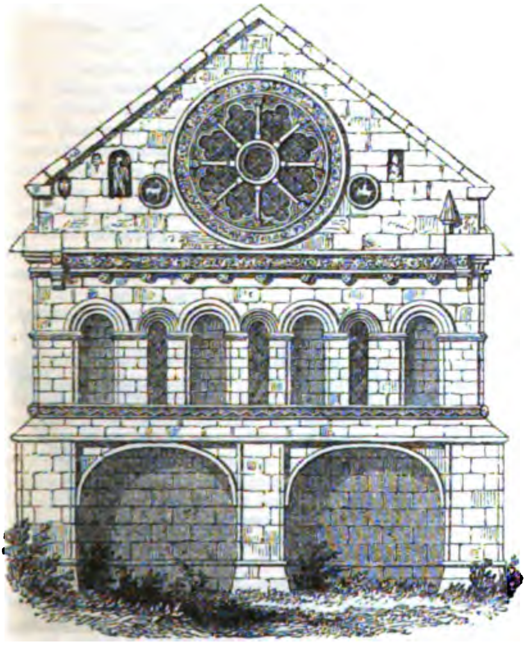


Fig. 180. BARFRESTON CHURCH.

their successive reigns; and it is evident that the churches attached to them were the most decorated parts, as respected their architecture. The six principal of these were, St. Germain's, in Cornwall; Colchester, in Essex; Tewkesbury, in Gloucestershire; St. Frideswide and St. Alban's, already mentioned; and Glastonbury, in Somersetshire. King selects the western portion of Tewkesbury as the grandest in England for effect and extent. The characteristics of *Anglo-Saxon Architecture* are detailed in the following subsection.

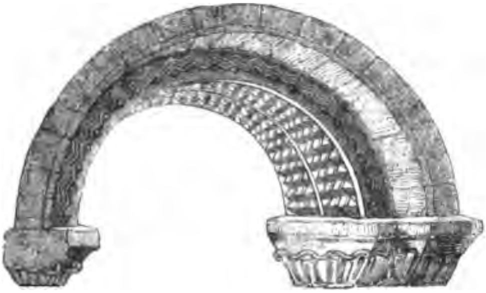


Fig. 181. SAXON ARCH.

390. *Arches.* — Always semicircular, often plain; sometimes decorated with a variety of mouldings on the sofite as well as on the face, the former being often entirely occupied by them. They are found double, triple, or quadruple, each springing from two columns, and generally cased with a different moulding, which is frequently double, thus making six or eight concentric circles of them; and as each of them projects beyond that under it, a moulding is placed under them, generally the same as that used upon the face. (See *fig.* 181.) *Columns.* — Single, cylindrical, hexagonal or octagonal, on square plinths; very few diameters in height. Shafts often ornamented with spiral or fluted carving, with lozenge, herring-bone, zigzag, or hatched work. (*Fig.* 182.) *Capitals.* — Indented with fissures of different lengths and forms, and in different directions. The divisions thus formed are variously sloped off, or hollowed out towards the top. (See the two examples, *fig.* 183., from the conventual church at Ely.) Occasionally the capitals have rude imitations of some member of a Grecian order, as in the crypt at Lastringham in Yorkshire, where volutes are used. (*Fig.* 184.) In their ornaments much variety is displayed, but the opposite ones are mostly alike. *Windows.* — Semicircular-headed, extremely narrow in proportion to their height, being sometimes not more than six or eight inches wide to a height of more than three feet, and splayed or bevelled off on the inside through the whole thickness of the wall. *Walls.* — Of very great thickness, and without any buttresses externally. Masonry of solid construction. *Ceilings and Roofs.* —Almost always open timbering. In crypts, as at York, Winchester, and a few other places, vaulting is to be found. *Ornaments*, except in capitals, in arches and on shafts of columns are very sparingly employed. (See Norman Ornaments also, in the following section on Norman Architecture, subsect. 397.) *Plans.* — Rectangular and parallelogrammic; being usually divided into a body and chancel, separated by an ornamented arch. The *chancel* sometimes of equal, and sometimes of less breadth than

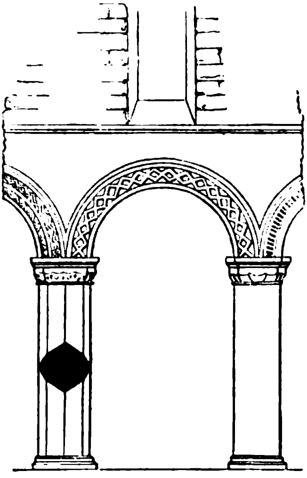


Fig. 182. ARCH, CONVENTUAL CHURCH, ELY.

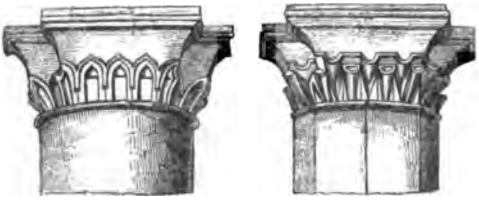


Fig. 183. TWO CAPITALS, CONVENTUAL CHURCH, ELY.

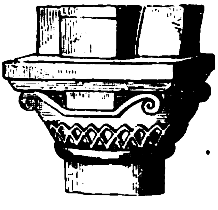


Fig. 184. CAPITAL FROM LASTRINGHAM

the nave, and terminated towards the east in a semicircle. In larger churches, there is a nave and two side aisles, the latter being divided from the former by ranks of columns; but no transepts appear till towards the latter part of the period. "Whether," observes Mr. Millers, in his account of Ely Cathedral, whose system we adopt, "their churches were ever higher than one tier of arches and a range of windows above (as at Ely), may be questioned. Richard, prior of Hexham, speaks of three stories, which implies another tier of arches; but if he is rightly so understood, this seems an exception from a general rule, for the church at Hexham is spoken of by all writers who mention it, as the glory of Saxon churches in the seventh century. Afterwards, about 970, a considerable change took place; transepts came into general use, with a square tower at the intersection, rising but little above the roof, and chiefly used as a lantern to give light to that part of the church. Towers were also erected at the west end: the use of them coincides with the introduction of bells, at least of large and heavy ones." The churches of this period were of small dimensions, and the comparative sizes of the Saxon and the Norman churches which followed is almost a criterion for their age.

391. King (*Munimenta Antiqua*, vol. iv. p. 240.) gives three æras of the Saxon style. 1. From Egbert, 598 to 872. 2. From Alfred to Canute and Harold, 1036. 3. To the Norman conquest. He selects no less than thirty-seven examples of Saxon ornaments from mouldings on doorways only. As examples of the periods he adduces, of the *first*, *Barfreston* in Kent; of the *second*, the nave and choir of *Christ Church Cathedral*, Oxford, and Canute's great entrance gate at *St. Edmundsbury*; of the *third*, *Southwell*, Notts, and *Waltham Abbey*, Essex. It has been questioned by antiquaries whether any Saxon remains actually exist in the country; but, admitting their arguments, which are founded on references to records — no mean authorities, — it must be recollected that, on their own showing, some of these trench so close upon the period of the Conquest as to show that the Saxon style might have prevailed in them, for the general change of style in any art is not effected in a day. If we look for examples coeval with the Saxons themselves, and without controversy to be attributed to them, they will, perhaps, be found only in crypts and baptismal fonts; for many churches were rebuilt by the Normans, who left these parts untouched. The castles of Roman or Saxon foundation were, Richborough, in Kent; Castletown, in Derbyshire; Porchester, in Hampshire; Pevensey, in Sussex; Castor, in Norfolk; Burgh, in Suffolk; Chesterford, in Essex; Corfe, Dorset; Exeter Castle gateway; Dover, in Kent; and Beeston, in Cheshire.

SECT. II.

NORMAN ARCHITECTURE.

392. From the landing of William in 1066, architecture received an impulse, indicated in various styles, which lasted till the time of the Tudors; when, as we shall hereafter see, it gave way to one altogether different. That called the Norman style, which continued from 1066 to nearly 1200, comprised the reigns of William I., William II., Henry I., Stephen, Henry II., and Richard I. The twelfth century exhibited a rage for building in Britain more violent than has been since seen. The vast and general improvements that were introduced into fabrics and churches in the first years of this century are thus described by a contemporary writer (*Orderic. Vital. Hist. Eccles.*, lib. x. p. 788.): — "The cathedrals, and abundance of churches, newly built in all parts of the country, the great number of splendid cloisters and monasteries, and other residences for monks, that were there raised, sufficiently prove the happiness of England under the reign of Henry I. Peace and prosperity were enjoyed by the religious of all orders, who lent their whole power to increase the magnificence and splendour of divine worship. The ardent zeal of the faithful prompted them to rebuild their houses, and especially their churches, in a more suitable manner. Thus the ancient edifices raised in the days of Edgar, Edward, and other Christian kings, were taken down, and others of greater magnitude, beauty, and more elegant workmanship, were reared in their stead to the glory of God." As an example of the fervour with which these objects were carried into effect, we cite the following instance, quoting from Dr. Henry, upon whom we have drawn, and shall draw, rather largely. "When Joffred, abbot of Croyland, resolved to rebuild the church of his monastery in a most magnificent manner (A.D. 1106), he obtained from the archbishops of Canterbury and York a bull dispensing with the third part of all penances for sin to those who contributed any thing towards the building of that church. This bull was directed not only to the king and people of England, but to the kings of France and Scotland, and to all other kings, earls, barons, archbishops, bishops, abbots, priors, rectors, presbyters, and clerks, and to all true believers in Christ, rich and poor, in all Christian kingdoms. To make the best use of

this bull, he sent two of his most eloquent monks to proclaim it over all France and Flanders; two other monks into Scotland; two into Denmark and Norway; two into Wales, Cornwall, and Ireland; and others into different parts of England. By this means (says the historian) the wonderful benefits granted to the contributors to the building of this church were published to the very ends of the earth; and great heaps of treasure, and masses of yellow metal, flowed in from all countries upon the venerable abbot Joffred, and encouraged him to lay the foundations of his church. Having spent about four years in collecting mountains of different kinds of marble from quarries, both at home and abroad, together with great quantities of lime, iron, brass, and other materials for building, he fixed a day for the great ceremony of laying the foundation, which he contrived to make a very effectual mean of raising the superstructure; for on the long-expected day, the feast of the holy virgins Felicitas and Perpetua, an immense multitude of earls, barons, and knights, with their ladies and families, of abbots, priors, monks, nuns, clerks, and persons of all ranks, arrived at Croyland to assist at this ceremony. The pious abbot Joffred began by saying certain prayers, and shedding a flood of tears on the foundation. Then each of the earls, barons, knights, with their ladies, sons, and daughters, the abbots, clerks, and others, laid a stone, and upon it deposited a sum of money, a grant of lands, tithes, or patronages, or a promise of stone, lime, wood, labour, or carriages for building the church. After this the abbot entertained the whole company, amounting to five thousand persons, to dinner. To this entertainment they were well entitled; for the money and grants of different kinds which they had deposited on the foundation stones were alone sufficient to have raised a very noble fabric." This spirit extended throughout the island; for, in Scotland, David I. raised thirteen abbeys and priories, some of them on a scale of considerable magnificence, besides several cathedrals and other churches.

393. The common people of the country, and the burgesses in the towns, were not much better lodged than in the previous age; their condition, indeed, was not improved. In London, towards the end of the twelfth century, the houses were still built of timber, and covered with reeds or straw. The palaces, however, or rather castles, of the Anglo-Norman kings, nobility, and prelates, were on a very superior construction. William of Malmesbury says that the Anglo-Saxon nobility squandered their ample means in low and mean dwellings; but that the French and Norman barons lived at less expense, though dwelling in large and magnificent palaces. The fact is, that among these latter the rage for erecting fortified castles was quite as great as that of erecting ecclesiastical buildings among the prelates. The system became necessary, and was induced as well by the previous habits of the country they had left, as by their situation in the island. Surrounded by vassals whom they held in subjection, and whom they depressed and plundered in every way, they were so detested by them that deep fosses and lofty walls were necessary for their security. The Conqueror himself, aware that the want of fortified places had no less assisted his conquest than it might his expulsion, resolved to guard against such a contingency by the strong castles which he placed within the royal demesnes. Matthew Paris observes that William excelled all his predecessors in the erection of castles, in executing which he harassed his subjects and vassals. So much was the practice a matter of course, that the moment one of the nobility had the grant of an estate from the crown, a castle was built upon it for his defence and residence; and this spirit was not likely to be diminished by the disputes relative to the succession in the following reigns. William Rufus, according to the statement of Henry Knighton, was as much addicted to the erection of royal castles and palaces as his father, as the castles of Dover, Windsor, Norwich, and others sufficiently prove; and it is certain that no monarch before him erected so many and noble edifices. Henry I. followed in his taste; but in the reign of Stephen, 1135 to 1154, says the author of the *Saxon Chronicle*, every one who had the ability built a castle, and the whole kingdom was covered with them, no fewer than 1115 having been raised from their foundations in the short space of nineteen years; so that the expression is by no means stronger than is justified by the fact.

394. It will be proper here to give the reader some concise general description of these structures, which served for residence and defence. The situation chosen for a castle was usually on an eminence near a river. Its figure on the plan was often of great extent, and irregular in figure; and it was surrounded by a deep and broad ditch, called the *fosse*, which could be filled with water. An outwork, called a *barbican*, which was a strong and lofty wall, with turrets upon it, and designed for the defence of the great gate and drawbridge, was placed before the latter. Within the ditch, towards the main building, was placed its wall, about 8 or 10 ft. thick, and from 20 to 30 ft. high, with a parapet and embrasures, called *crennels*, on the top. At proper intervals above the wall square towers were raised, two or three stories in height, wherein were lodged some of the principal officers of the proprietor of the castle, besides their service for other purposes; and, on the inside, were apartments for the common servants or retainers, granaries, storehouses, and other necessary offices. On the top of the wall, and on the flat roofs of the towers, the defenders were placed in the event of a siege; and thence they discharged arrows, darts,

and stones on their assailants. The great gate was placed in some part of the wall flanked with a tower on each side, with rooms over the entrance, which was closed with massive oak folding doors, frequently plated with iron, and an iron grate, or *portcullis*, which, by machinery, was lowered from above. Within this exterior wall, or ballium, was, in the more extensive castles, the outer *ballium*, which was a large open space or court, wherein a church or chapel was usually placed. Within the outer ballium was another ditch, with wall, gate, and towers, inclosing the inner ballium or court, in which was erected the large tower, or *keep*. It was a large fabric, some four or five stories high, whose enormously thick walls were pierced with very small apertures, serving barely as windows to the gloomy apartments upon which they opened. This great tower was the dwelling of the owner of the castle; and in it was also lodged the constable, or governor. It was provided with underground dismal apartments for the confinement of prisoners, whence the whole building received the appellation of *dungeon*. In the keep was also the great hall, in which the friends and retainers of the owner were entertained. At one end of the great halls of castles, palaces, and monasteries, a low platform was raised a little above the rest of the floor, called the *dais*, on which stood the principal table whereat persons of higher rank were placed. The varieties which occurred in the arrangement and distribution of castles were, of course, many, as circumstances varied; but the most magnificent were erected nearly on the plan we have just described, as may be gathered as well from their ruins as from an account by Matthew Paris of the taking of Bedford Castle by Henry III., A.D. 1224. This castle, we learn from him, was taken by four assaults. In the first was taken the barbican; in the second, the outer ballium; in the third attack, the miners threw down the wall by the old tower, where, through a chink, at great risk, they possessed themselves of the inner ballium; on the fourth assault, the miners fired the tower, which thereby became so injured and split that the enemy thereon surrendered. The keeps of which we have spoken are such extraordinary edifices, that we think it right to place before the reader, from the *Discourses upon Architecture* of our late much esteemed and learned friend, the Rev. James Dallaway, the following table of some of the principal ones of the Norman æra.

Names.	Length.	Breadth.	Height.	Division of Rooms.	Dates and Founders.
			Internal Square, or Oblong.		
Tower of London	116 ft.	96 ft.	— ft.	By semicircular arches.	William the Conqueror.
Porchester	115	65	—	Four floors.	
Canterbury	88	80	50	Two walls continued from the base to the top.	
Rochester	75	72	104	By semicircular arches.	Gundulph (Bishop).
Dover	—	—	92		
Colchester	140	102	—	Three large rooms on each floor.	
Norwich	110	92	70	- - - - -	Roger Bigod.
Ludlow	—	—	110	Four stories.	Roger de Laci.
Hedingham	62	55	100	Three tiers above basement.	
Guildford	42	47	—		
Oxford	-	-	-	- - - - -	Robert D'Oiley.
Bamborough	-	-	-	- - - - -	1070.
Richmond	-	-	-	Vault supported by a single octangular pillar.	1100.
Newcastle upon Tyne	82	62	54	By internal arches and door cases in Norman style.	1080. Robert Curthoise.
Corfe	72	60	80		
			Round, or Polygonal.		
Arundel	69	57	—	Roof open in the centre, straight buttresses.	1070. Roger Montgomeri.
Conisburgh	22 diameter.			Three floors, two of them state apartments.	1070. W. de Warren.
York	64	45	-	Four segments of circles	1068. William the Conqueror.
Tunbridge	64	50	—		
Berkeley	-	-	-	Circular, flanked by four small towers.	1120. Rob. Fitzharding.
Lincoln	-	-	—	- - - - -	1086. William the Conqueror.
Oxford	-	-	-	Polygon, flanked by three square towers.	
Windsor	90	85	—	- - - - -	Rebuilt by Edw. III.
Durham	63	61	—	- - - - -	Heightened in 1830.

395. Gundulph is said to have introduced the architectural ornaments of the Norman style into the interior as well as on the exterior of castles. The use of battlements, loop-

holes, and open galleries, or machicolations, was certainly, as our author above quoted remarks, known to the Romans.

> ——— Troes contra, defendere saxis
> Perque cavas densi tela intorquere fenestras. *Æn.* l. ix. 533.

The architects and artificers by whom the Norman works were planned and executed were men of great science and skill, and the names of several have most deservedly obtained a place in history. Gervase of Canterbury records that William of Sens, the architect of Archbishop Lanfranc in building his cathedral, was an artist of great talents; and that he not only made a complete model of the cathedral upon which he was employed, but of all the details of sculpture necessary for its execution, besides inventing machines for loading and unloading the vessels, and conveying the heavy materials, many whereof were brought from Normandy. Of Walter of Coventry, another architect of the age, Matthew Paris speaks in the highest terms, saying that "so excellent an architect had never yet appeared, and probably never would appear in the world." Dr. Henry on this very properly observes, "That this encomium was undoubtedly too high; but it is impossible to view the remains of many magnificent fabrics, both sacred and civil, that were erected in this period, without admiring the genius of the architects by whom they were planned, and the dexterity of the workmen by whom they were executed."

396. Of the twenty-two English cathedrals, fifteen retain parts of Norman erection, whose dates are pretty well ascertained; and by them the Norman manner was progressively brought to perfection in England. We subjoin the following enumeration of Norman bishops, who were either patrons of the art, or practising it themselves.

A. D.	Bishop, or Architect.	Works.
1059 to 1089	Aldred, Bishop of Worcester.	St. Peter's, Gloucester.
1077 to 1107	Gundulph, of Rochester.	Rochester, Canterbury, and Peterborough.
1086 to 1108	Maurice, of London.	Old St. Paul's Cathedral.
1093 to 1133	William de Carilepho.	Cathedral of Durham, but completed by Ranulph Flambard.
1080 to 1100	Lanfranc, of Canterbury.	
1107 to 1140	Roger, of Salisbury.	Cathedral at Old Sarum.
1115 to 1125	Ernulf, of Rochester.	Completed Gundulf's works at Rochester.
1123 to 1147	Alexander, of Lincoln.	Rebuilt his cathedral.
1129 to 1169	Henry of Blois, Bishop of Winchester.	Conventual churches of St. Cross and Rumsey, in Hampshire.
1158 to 1181	Roger, Archbishop of York.	

Of Norman architecture the principal characteristics are subjoined in the following subsection.

397. *Arches.*—Generally semicircular, as in the nave of Gloucester, here given (*fig.* 185.). Of larger opening than the Saxon, and their ornaments less minute; often bounded by a single moulding, though sometimes by more than one; occasionally without any moulding at all; the soffitt always plain. In the second story, two smaller equal arches under one larger, with a column of moderate size, or even comparatively slender, between them. In the third story (see *fig.* 186.), generally three together, the centre one higher and broader than the others, and opened for a window; but the whole three only occupy a space equal to that of the lower arch. *Arches of entrance* are profusely decorated (*fig.* 187., from Ely) with mouldings, foliage, wreaths, masks, figures of men and animals in relief, and all the fancies of the wildest imagination, in which every thing that is extravagant, grotesque, ludicrous, nay, even grossly indecent, is to be found. Before the end of the period — and we may almost say early in it — it exhibits examples of *pointed arches.* They are, however, sparingly introduced: one or more tiers appear in the upper stories of a building, whilst all the lower ones are circular. Sometimes they are intro-

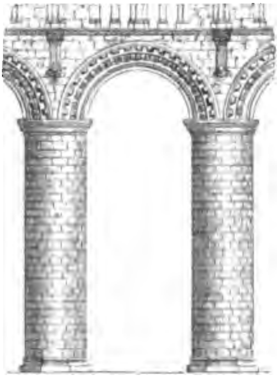


Fig. 185. ARCH FROM NAVE OF GLOUCESTER.

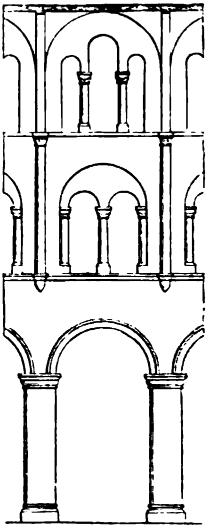


Fig. 186. THREE STORIES OF A NORMAN CATHEDRAL.

duced alternately, sometimes we find one capriciously inserted between several round ones; these are, for the most part, obtusely pointed, though occasionally they are the reverse. They are always wide, stand on heavy columns, or are decorated with mouldings, or both. The approaches to the pointed style were not strongly marked, but they were indicated; for the pointed style cannot be pronounced to have commenced until the sharp-pointed arch sprung from a slender column graced with a capital of carved foliage, and this it is not safe to place earlier than the reign of John. The arch which rises more than a semicircle does not very often occur; but it must be mentioned as exhibiting one of the varieties of the period. *Columns.* — These are of very large diameter relative to their heights and intervals. Their shafts are circular, hexagonal, and sometimes octagonal, on the plan; fluted, lozenged, reticulated, and otherwise sculptured. Sometimes they are square on the plan, and then accompanied by portions of columns or pilasters applied to them. Sometimes four columns are connected together, with or without angular pieces. They are much higher in proportion to their diameters than the Saxon columns heretofore described; and though their capitals are not unfrequently quite plain, they are more commonly decorated with a species of volute, or with plants, flowers, leaves, shells, animals, &c. The bases stand on a strong plinth, adapted on its plan to receive the combined and varied forms of the columns. *Windows*, are still narrow, and semicircular-headed; but they are higher, and often in groups of two or three together. *Ceilings*, usually, if not always, of timber, except in crypts, in which they are vaulted with stone, with groins mostly plain, yet sometimes ornamented on the edge, but universally without tracery. The White Tower of London, however, exhibits an example of a centre aisle covered with vaulting. Our belief is, and in it we are corroborated by the Rev. Mr. Dallaway, whose judgment we hold in no small esteem, that there is no instance of a genuine Anglo-Norman building which was intended to be covered with a stone roof or ceiling. This is not only indicated by the detail, but by the circumstance of the walls being insufficient (thick as they are) in solidity to resist the thrust. Peterborough, Ely, St. Peter's, Northampton, Steyning, Romsey, &c. are calculated and constructed to receive wooden roofs only. *Walls*, are of extraordinary thickness, with but few buttresses, and those of small projection; flat, broad, and usually without ornament. *Ornaments.*—Among these must be first named the ranges of arches and pilasters which had nothing to support, already incidentally mentioned, and which were intended to fill up void spaces, internally as well as externally, for the purpose of breaking up large masses of surface; they are very common on the inside of north and south walls, sometimes intersecting each other so as to produce those compartments that are alleged to have given rise to the pointed arch. The mouldings of the Saxon period continued much in use, and we ought, perhaps, to have given some of them, as belonging to the preceding section; and, indeed, should have so done, if, in the Norman style, they had not increased in number and variety, and had not also been employed in profusion about the ornamental arches just named, especially in conspicuous places on the outside, as in the west front especially. The most usual ornaments (*fig.* 188.) were, 1. The *chevron*, or *zigzag* moulding; 2. The *embattled frette;*

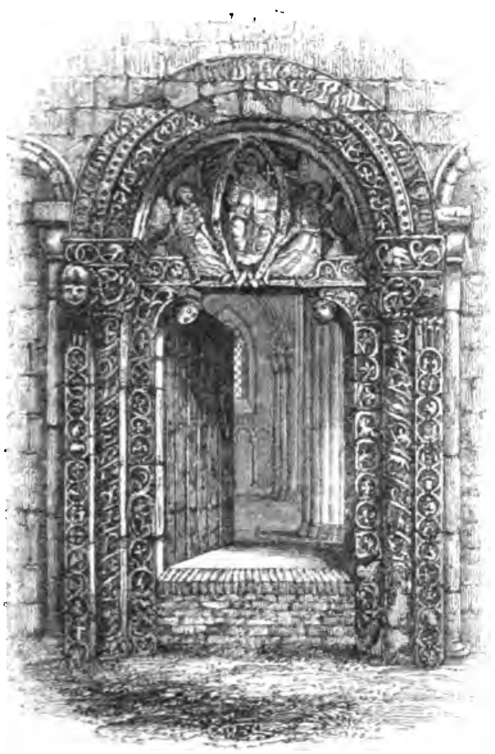


Fig. 187. PRIOR'S ENTRANCE AT ELY.

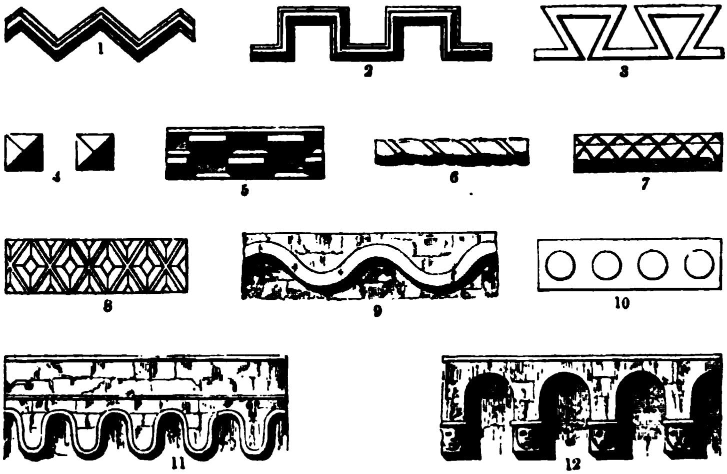


Fig. 188. NORMAN ORNAMENTS.

3. The *triangular frette;* 4. The *nail head;* 5. The *billet;* 6. The *cable;* 7. The *hatched;* 8. The *lozenge;* 9. The *wavy;* 10. The *pellet* moulding; 11. The *nebule.* The *torus* was used, as was also the *cavetto,* which were both of Grecian extraction. The chief of these ornaments, perhaps all, were used in the Saxon age, besides others which were occasionally employed, and which to designate by name would be difficult; such, for instance, as the *corbel-table* (12), which consists of small ranges of arches, resting on brackets sometimes decorated with carved heads, often introduced along the whole building immediately below the eaves or battlement. Sometimes carved heads are observed in the spandrels of arches, and are also used as capitals of the ornamented pilasters, or as corbels, to support what is called the canopy, or exterior semicircle of moulding on arches of entrance, or above the keystones of those arches. There are instances of whole figures over doors in mezzo-rilievo, which Millers observes was the nearest approach the Normans seem to have made to a statue. *Plans.* — The churches of this period are always with transepts, and a tower at the intersection, loftier than heretofore, but without spires over them. There are rising from them stories of arches, one above the other; and the eastern ends are semicircular. Though much of the Saxon style is retained, there is, from the larger dimensions of the edifices of this period, a much more impressive air of magnificence than had before appeared. Millers very truly says, that the churches were "in all dimensions much ampler, with a general air of cumbrous massive grandeur. The Normans were fond of stateliness and magnificence; and though they retained the other characteristics of the Saxon style, by this amplification of dimensions they made such a striking change as might justly be entitled to the denomination which it received at its first introduction among our Saxon ancestors, of *a new style of architecture.*" The criterion between the Saxon and Norman styles, of enlarged dimensions, is too vague to guide the reader in a determination of the age of buildings of this period; for it is only in large edifices, such as cathedral and conventual churches, with their transepts, naves, side aisles, and arches in tier above tier, that this can be perceptible. There are many parish churches of this age, whose simplicity of form and small dimensions have been mistaken for Saxon buildings; and which, from not possessing any of the grander Norman features, have been assigned to an earlier age. The distinction ascertainable from heights of columns, — namely, taking the height of the Saxon column at from four to six diameters, and that of the Norman at only two,—will, we fear, be insufficient to decide the question in cases of doubt; but it must be admitted this is one of the means which, in some measure, would lead us to an approximate judgment of the matter, and a careful observation and comparison of specimens would make it more definite. We shall here merely add, that the first Norman architects, by the lengthened vista of the nave, uninterrupted by any choir screen, produced a sublime and imposing effect by the simple grandeur and amplitude of dimensions in their churches.

398. *Examples.* — Examples of Norman architecture in English *cathedral churches* are to be found at *Ely,* in the western towers and nave; at *Bristol,* in the elder Lady Chapel, and Chapter House; at *Canterbury* in the choir, and the round part called Becket's Crown; at *Norwich,*

in the nave and choir; at *Hereford*, in the transept tower and choir; at *Wells*, in the nave and choir; at *Chester*, in the Chapter House; at *Chichester*, in the presbytery; at *Peterborough*, in the transept. In the *conventual churches*, for examples we may refer the reader to *Llantony*, near Monmouth; the nave and west front of *Fountains*, Yorkshire; the nave and chapel of *St. Joseph*, at Glastonbury; the west front at *Selby*, in Yorkshire; many parts at *St. Alban's;* the choir at *Wenlock*, in Shropshire; *Cartmell*, in Lancashire; *Furness;* West End, at *Byland*, with the wheel window, and the south transept; parts of *Bolton*, in Yorkshire; part of *Brinkbourn*, in Northumberland; part of *Edmondsbury*, in Suffolk; and *St. John's Church*, at Chester. For examples of parochial churches, *Melton*, Suffolk; *Sotterton* and *Sleaford*, Lincolnshire; *Christchurch*, Hampshire; *Sherbourn Minster*, Dorset; *Winchelsea*, *Steyning*, and *New Shoreham*, Sussex; chancel of *St. Peter's*, Oxford; *Earl's Barton Tower*, Northamptonshire; *West Walton Tower*, Norfolk; *Iffley*, Oxfordshire; *Castle Rising*, Norfolk; *St. Margaret's Porch*, at York; *St. Peter's Church*, Northampton; besides several round or polygonal bell-towers, both in Suffolk and Norfolk, — may be referred to. Examples of *military Norman architecture*, from 1070 to 1270, were at *Launceston*, Cornwall; *Arundel*, Sussex; *Windsor*, in Berks (rebuilt); *Tower of London;* the square keeps of *Hedingham*, Essex; *Caerphilly*, Glamorgan; *Carisbrook*, Isle of Wight; *Porchester*, Hants (1160); *Guildford*, Surrey; *Bamborough*, Northumberland; *Kenilworth*, Warwickshire; *Richmond*, Yorkshire; *Cardiff*, Glamorganshire; *Canterbury*, Kent; *Oxford* (1071); *Newcastle*, Northumberland (1120); *Gisborough*, Yorkshire (1120); *Castle Rising*, Norfolk; *Middleham*, Yorkshire; *Cockermouth*, Cumberland; *Durham* (1153); *Lincoln* (1086); *Berkeley*, Gloucestershire (1153); *Lancaster; Orford*, Suffolk, polygonal (1120); *Ludlow*, Salop (1120); *Kenilworth*, enlarged (1220); *Warkworth*, Northumberland, square, with the angles cut off; *Denbigh; Beeston*, Cheshire; *Hawarden*, Pembrokeshire.

Sect. III.

EARLY ENGLISH ARCHITECTURE.

399. The next period of architecture in Britain which comes under our consideration, following, as we consider it, the sensible classification of the Rev. Mr. Millers, is that which he has denominated the *early English style*, whose duration was from about 1200 to 1300; extending, therefore, through the reigns of John, Henry III., and Edward I., during which the building of churches and monasteries was still considered one of the most effectual means of obtaining the pardon of sin, and consequently the favour of Heaven. In the thirteenth and fourteenth centuries, the churches built in Britain were almost innumerable.

400. We have already noticed (chap. ii. sect. xv.) the introduction of the pointed arch into architecture; a feature which completely changed, from all that previously existed, the character of the edifices to which it was applied. If any service could be rendered to the history of the art, or if the solution of the problem, "who were its inventors?" could throw any useful light on the manners and customs of the people that first adopted it, we should be the last to relinquish the investigation. The question has furnished employment to many literary idlers, especially at the universities, whose time might, perhaps, have been more usefully employed in looking after the young men under their charge, especially as they have all, except Whittington, done little, if any thing, towards advancing a knowledge of the subject, which involves information possessed by few of them, of whom the latest have done the least.

401. During the reign of Henry III. alone, no less a number than 157 abbeys, priories, and other religious houses were founded in England. Several of our cathedrals and conventual churches in a great part belong to this period, in which the lancet or sharp-pointed arch first appeared in the buildings of this country, though on the Continent it was used nearly a century earlier. The great wealth of the clergy, added to the zeal of the laity, furnished ample funds for the erection of the magnificent structures projected; but it was with extreme difficulty that workmen could be procured to execute them. With the popes it was, of course, an object that churches should be erected and convents endowed; hence they granted by their bulls many indulgences to the Society of Freemasons, which had greatly increased in its numbers. These Freemasons appear to have ranged from one nation to another (*Wren's Parentalia*), as they found churches to be built: their government was regular, and when they fixed near the building in hand they made a camp of huts. A surveyor governed in chief; every tenth man was called a warden, and overlooked each nine. "Those who have seen the account in records of the charge of the fabrics of some of our cathedrals, near 400 years old, cannot but have a great esteem for their economy, and admire how soon they erected such lofty structures." It was in the

course of this period that sculpture was first made extensively available for architectural decoration. The cathedral, conventual, and other churches built in Britain, began to be ornamented on the outside with statues of various dimensions in basso and alto rilievo. They were not equal in execution to those of France, which have also had the additional good fortune to have been better preserved, from their exposure to seasons less inclement, and to an atmosphere unimpregnated with the smoke of coal.

402. Great improvements seem to have taken place in the castles of the time; they still continued to serve for the dwelling and defence of the prelates and barons of the country. The plans of them were generally similar to those already described; but it must still be conceded that the inhabitants and owners of them sacrificed their convenience to their security, which seems to have been the chief concern in the construction of their castles, whose apartments were gloomy, whose bed-chambers were few and small, whose passages were narrow and intricate, and their stairs steep and dark. The plan, however, as Mr. Dallaway observes, "which allowed of enlarged dimensions, and greater regularity and beauty in the architecture of the towers, owes its introduction into England to King Edward I. We may, indeed, consider his reign as the epoch of the grand style of accommodation and magnificence combined in castle architecture. When engaged in the Crusades, he surveyed with satisfaction the superior form and strength of the castles in the Levant and in the Holy Land." Of the five castles erected by him in Wales, Caernarvon (*fig.* 189.), Conway (*fig.* 190.), Harlech, and Beaumaris still retain traces of their ancient magnificence; but that of Aberystwith has scarcely a feature left. Caernarvon Castle consisted of two distinct parts: one military, and suited to the reception of a garrison; the other palatial. The ground plan was oblong, unequally divided into a lower and an upper ward. Of the towers, which are all polygonal, the largest, from some tradition called the Eagle Tower, has three small angular turrets rising from it; the others having but one of the same description. "The enclosing walls," continues Mr. Dallaway, "are seven feet thick, with *alures* and parapets pierced frequently with *œillet* holes. A great singularity is observable in the extreme height both of the great entrance gate and that which is called the Queen's. Leland observes of the portcullises at Pembroke, that they were composed *ex solido ferro*. In confirmation of the opinion that the royal founder adopted the form of such gates of entrance from the East, similar ones are almost universal in the castles, mosques, and palaces of the Saracens, which he had so frequently seen during the Crusades. The tower of entrance from the town of Caernarvon is still perfect, and is the most handsome structure of that age in the kingdom. It is at least 100 ft. high; and the gateway, of very remarkable depth, is formed by a succession of ribbed arches, sharply pointed. The grooves for three portcullises may be discovered; and above them are circular perforations, through which missile weapons and molten lead might be discharged upon the assailants. In the lower or palatial division of the castle stand a large polygonal tower of four stories, which was appropriated to Queen Eleanor, and in which her ill-fated son was born, and another which was occupied by the king, of a circular shape externally, but square towards the court. The apartments in the last mentioned are larger, and lighted by windows with square heads, and intersected with carved mullions. There is a singular contrivance in the battlements, each of which had an excavation for the archers to stand in, pointing their arrows through the slits; and, a curious stratagem, the carved figures of soldiers with helmets, apparently looking over the parapet. This device is repeated at Chepstow." The ornamental character of the architecture at Caernarvon and Conway is rather ecclesiastical, or conventual, than military. At Conway, as has been well observed by an anonymous author, "what is

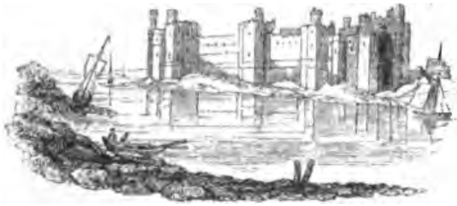


Fig. 189. CAERNARVON CASTLE.

Fig. 190. CONWAY CASTLE.

called the Queen's Oriel is remarkable for the fancy, luxuriance, and elegance of the workmanship. Nor is the contrivance of the little terraced garden below, considering the history of the times, a matter of small curiosity, where, though all the surrounding country were hostile, fresh air might be safely enjoyed; and the commanding view of the singularly beautiful landscape around, from both that little herbary or garden, and the bay window or oriel, is so managed as to leave no doubt of its purpose."

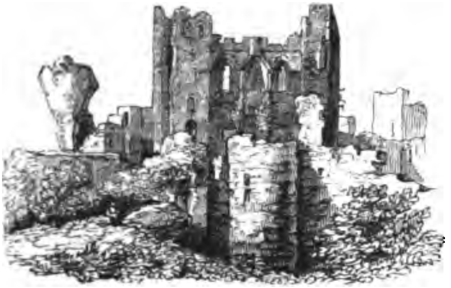


Fig. 191. CAER-PHILLY CASTLE.

403. The model of Conway Castle has little resemblance to that we have just left. It resembles rather the fortresses of the last Greek emperors, or of the chieftains of the north of Italy. The towers are mostly circular, as are their turrets, with a single slender one rising from each; and machicolations, not seen at Caernarvon, are introduced. The greater part of the castles of Wales and Scotland for the defence of the marches were built in the reign of Edward I. On the subjugation of the former country, and its partition into lordships among Edward's followers, many castles were reared upon the general plan of those he had erected, though varying in dimensions and situation, according to the means of defence proposed to be secured to their founders and possessors. We may here observe, that in the castle at Conway Edward I. erected a hall 129 ft. by 31, and 22 ft. high, which is formed to suit the curvature of the rock; and that from that period no residence of consequence, either for the nobility or feudal lords, was erected without one, varying, however, of course, in their minuter parts, according to circumstances, and in degree of magnificence.

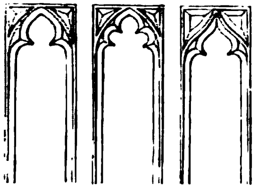


Fig. 192. TREFOIL AND CINQUEFOIL HEADS.

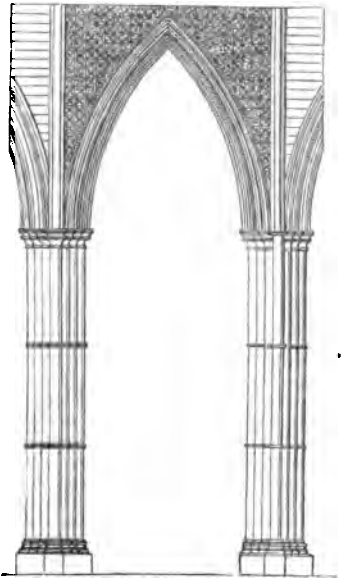


Fig. 193. COLUMNS OF WESTMINSTER ABBEY.

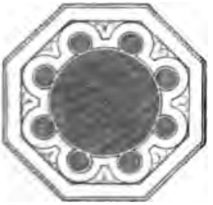


Fig. 194. PLAN OF COLUMN.

404. Caer-Philly Castle, in Glamorganshire (*fig.* 191.), was another of the castles of this period. It was the strong-hold of the De Spencers in the reign of the second Edward. Its vallations and remains are very extensive. The hall was much larger than that at Conway.

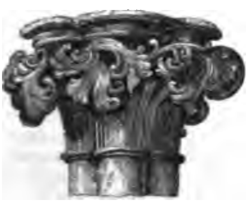


Fig. 195. CAPITAL OF COLUMN.

405. The characteristics of this style are, that the *arches* are sharply (lancet) pointed, and lofty in proportion to their span. In the upper tiers two or more are comprehended under one, finished in *trefoil* or cinquefoil heads (*fig.* 192.) instead of points, the separating columns being very slender. *Columns* on which the arches rest (*fig.* 193.) are very slender in proportion to their height, and usually consist of a central shaft surrounded by several smaller ones (*fig.* 194.). The base takes the general form of the cluster, and the capital (*fig.* 195.) is frequently decorated with foliage very elegantly composed. The *windows* are long, narrow, and lancet shaped, whence some writers have called this style the *Lancet* Gothic. They are divided by one plain mullion,

or in upper tiers by two at most, finished at the top with some simple ornament, as a lozenge or a trefoil. They have commonly small marble shafts on each side, both internally and externally; two, three, or more together at the east or west end, and tier above tier. *Roofs* are high pitched and the ceilings vaulted, exhibiting the first examples of arches with cross springers only, which in a short period diverged into many more, rising from the capitals of the columns, and almost overspreading the whole surface of the vaulting. The longitudinal horizontal line which reigned along the apex of the vault was decorated with bosses of flowers, figures, and other fancies. *Walls* much reduced in thickness from those of the preceding period: they are, however, externally strengthened with buttresses, which, as it were, lean against them for the purpose of counteracting the thrust exerted by the stone vaults which form the ceilings, and which the walls and piers by their own gravity could not resist. The buttresses are moreover aided in their office by the pinnacles, adorned with crockets at their angles, and crowned with finial flowers, by which they are surmounted. *The ornaments* now become numerous, but they are simple and elegant. The mouldings are not so much varied as in the Norman style, and are generally, perhaps universally, formed of some combination of leaves and flowers, used not only in the circumference of arches, especially of windows, but the columns or pilasters are completely laid down with them. Trefoils, quatrefoils, cinquefoils, roses, mullets, bosses, pateræ, &c. in the spandrils, or above the keystones of the arches and elsewhere. The ornamental pinnacles on shrines, tombs, &c. are extremely high and acute, sometimes with and sometimes without niches under them. In east and west fronts the niches are filled with statues of the size of life and larger, and are crowned with trefoil, &c. heads, or extremely acute pediments, formed by the meeting of two straight lines instead of arcs. All these ornaments are more sparingly introduced into large entire edifices than in smaller buildings or added parts. *The plans* are generally similar to those of the second period; but that important feature the tower now begins to rise to a great height, and lanterns and lofty spires are frequent accompaniments to the structure. It will naturally occur to the reader, that in the transition from the second to the third style, the architects left one extreme for another, though it has been contended that the latter has its germ in the former. However that may be, the period of which we are now speaking was undoubtedly the parent of the succeeding styles, and that by no very forced or unnatural relationship.

406. The principal examples of the early English style in the cathedral churches of England are to be seen at *Oxford*, in the chapter-house. *Lincoln*, in the nave and arches beyond the transept. *York*, in the north and south transept. At *Durham*, in the additional transept. *Wells*, the tower and the whole western front. *Carlisle*, the choir. *Ely*, the presbytery. *Worcester*, the transept and choir. *Salisbury*, the whole cathedral; the only unmixed example. At *Rochester*, the choir and transept. "It is well worthy of observation," says Mr. Dallaway, "that though the ground plans of sacred edifices are, generally speaking, similar and systematic, yet in no single instance which occurs to my memory do we find an exact and unvaried copy of any building which preceded it in any part of the structure. A striking analogy or resemblance may occur, but that rarely."

407. The examples of conventual architecture of this period, to which we beg to refer the reader, are those of *Lanercost*, in Cumberland; *Rivaulx*, Yorkshire; *Westminster Abbey*. At *Fountains*, the choir and east end; *Tinterne Abbey*, in Monmouthshire; *Netley*, Hampshire; *Whitby*, in Yorkshire; *Valle Crucis*, in Denbighshire; *Ripon Minster* and the south transept of *Beverley Minster*, in Yorkshire; *Milton Abbey*, Dorsetshire; *part of the nave of St. Alban's; Tinemouth* and *Brinkbourn*, Northumberland; *Vale Royal*, in Cheshire; and the eastern façade of *Howden*, in Yorkshire.

408. Among the examples of parochial churches in this style are *Grantham*, in Lincolnshire, whose tower is 180 ft. high; *Attelborough*, in Norfolk; *Higham Ferrars*, in Northamptonshire; *St. Michael, Coventry; Truro*, in Cornwall; *Witney*, in Oxfordshire; *Stratford upon Avon*, in Warwickshire; *St. Peter Mancroft*, Norwich; *Boston*, Lincolnshire, remarkable for its lantern tower rising 262 ft. from the ground, and perhaps almost belonging to the succeeding period; *St. Mary, Edmund's Bury*, Suffolk; *Maidstone*, in Kent; and *Ludlow*, in Shropshire.

Sect. IV.

ORNAMENTED ENGLISH ARCHITECTURE.

409. The fourth period in the architecture of Britain is that which Mr. Millers calls the *Ornamented English Style*, which begins about 1300 and lasts till 1460, and comprises, therefore, the latter portion of the reign of Edward I., and the reigns of Edward II., Edward III., Richard II., Henry IV., Henry V., and Henry VI.

410. This æra has by Dallaway and others been subdivided into two parts, viz. first

from 1300 to 1400, which they call that of the Transition Style or pure Gothic, and from 1400 to 1460, called the Decorated Gothic; but the change between the latest examples of the first and the earliest of the last is marked by such nice and almost imperceptible distinctions, that it is next to impossible to mark their boundaries with precision; and we have therefore preferred adhering, as we have in the other ages of the art, to the arrangement adopted by Mr. Millers. In the early part of the period the change, or rather progress, was extremely slow, and marked by little variation, and, indeed, until 1400, the style can scarcely be said to have been perfected; but after that time, it rapidly attained all the improvement whereof it was susceptible, and so proceeded till about 1460; after which, as we shall hereafter see, it assumed an exuberance of ornament, beyond which as it was impossible to advance, it was in a predicament from which no change could be effected but by its total abandonment.

411. Notwithstanding the wars of the rival houses of York and Lancaster, which occupied a considerable portion of the interval whereof we are speaking, and deluged, as the reader will recollect, our land with the blood of the bravest of men, the art did not appear to suffer; a circumstance apparently extraordinary, but satisfactorily accounted for by the zeal of both the contending parties for the religion they in common professed. True it is that the taste for founding and building monasteries and churches was not so universal as in the period last described; the decline, however, of that taste might in some measure have arisen not only from the unhappy state of the country just alluded to, but also from the doubts raised in the minds of many persons of all ranks by Wickliffe and his followers as to the merit attached to those pious and expensive works. "It cannot," says Henry, "be denied that the style of sacred architecture commonly called Gothic continued to be greatly improved, and in the course of this period was brought to the highest perfection." To account in some measure for this, it must be recollected that during the civil wars the superior ecclesiastics were confined to their cloisters, as few of them had taken an active part in the dispute which agitated the realm; and, indeed, some of the finest structures now remaining were reared from the accumulation of wealth amassed by instigating the noble and affluent to contribute to churches built under their own inspection. The choir at Gloucester, a most beautiful example, was completed during these turbulent times by Abbot Sebroke, together with the arcade that supports the magnificent tower of that cathedral.

412. During this period the efforts of painting and sculpture were superadded to those of architecture; and to these must be joined the enchanting effects produced by expanded windows glowing with the richest colours that stained glass could bestow on them. To enter into a history of the rise, progress, and perfection of this art, would here be out of place. A separate work would be required to trace it from its introduction in this country as connected with our art in the reign of Henry III., to that point when it reached its zenith in the fifteenth century. Dallaway observes, with much truth, that it is a vulgar error to suppose the art was ever lost, inasmuch as we had eminent professors of it in the reign of Charles I.

413. In military architecture, from the reign of Edward III. to the close of the contention between the houses of York and Lancaster, many improvements were effected. Within that period a great number of the castellated edifices of which the country could boast were erected or renewed. Their style is marked by turrets and hanging galleries over the salient angles and gateways, of great variety in design. In the fortress at Amberley, in Sussex, built by William Rede, Bishop of Chichester, about 1370, and one of the ablest geometricians of the age, the ground plan is nearly a parallelogram with four large towers at the angles, not projecting externally, but inserted into the side walls. Of this æra is also, at Swansea Castle, the lofty perforated parapet or arcade, through which the water was conveyed from the roof. Upon this plan Henry Gower, Bishop of St. David's, in 1335, improved, in his magnificent castellated palace at Llanphey Court.

414. From the circumstance of the circuit of many of the castles encompassing several acres of ground, the base court was proportionably spacious; hence the halls and other state apartments were lighted by windows, smaller, but similar in form, to those used in churches. The rest of the apartments were unavoidably incommodious, defence being the chief consideration. In the castles and palaces of the period, the *halls*, which formed a principal feature in them, require some notice. The earliest whereof mention is made was that built by William Rufus in his palace at Westminster. Hugh Lupus erected one at Chester, and one was executed for Robert Consul at Bristol. Others we find erected by Henry I. at Woodstock and Beaumont in Oxford; probably of rude construction, and divided into two aisles by piers of arcades or timber posts. In the following century, when castles began to be constantly inhabited, and space became requisite for holding the numerous feudal dependents on various occasions, the size of the hall was of course increased, and internal architecture and characteristic ornaments were applied to it. At the upper end, where the high table was placed, the floor was elevated, forming a *haut pas* or *dais*, a little above the general level of the floor. The example afforded by Edward III. at

Windsor was followed during his own and the succeeding reign. The halls of Westminster and Eltham were rebuilt by Richard II.; Kenilworth by John of Gaunt; Dartington, in Devonshire, by Holland Duke of Exeter. Crosby Hall, in London, was finished by the Duke of Gloucester, afterwards Richard III. We here subjoin the dimensions of some of the principal halls in castles and palaces before the end of the fifteenth century, ranged in order of their size: —

	Length in feet.	Breadth in feet.	Height in feet.
Westminster (1397) - - -	228	66	92
Durham Castle - - - -	180	50	36
Conway (roof laid on stone ribs) - -	129	31	22
Bristol (divided by upright beams of timber)	108	50	—
Windsor (ancient) - - - -	108	35	—
Eltham (1386) - - - -	100	36	55
Chester - - - - -	99	45	—
Kenilworth (1300) - - -	90	50	—
Raby - - - - -	90	36	—
Lumley - - - - -	90	—	—
Swansea - - - - -	88	30	—
Castle Hall, Leicester - - -	78	51	24
Spofforth - - - - -	76	36	—
Dartington (1476) - - - -	70	40	44
Caerphilly - - - - -	70	—	35
Crosby Place - - - -	69	27	38
Goodrich - - - - -	65	28	—
Warwick - - - - -	62	35	25
Second one at Swansea - - -	58	33	—
Berkeley - - - - -	51	32	—

415. Generally, in respect of plan, the internal arrangement of these halls was very similar. The high table, as we have observed, was elevated on a platform above the level of the floor, and was reserved for the lord and his family, with the superior guests. Round the walls separate tables and benches were distributed for the officers of the household and dependents. The centre was occupied by the great open fire-place, directly over which in the roof was placed a turret, denominated a louvre, for conveying away the smoke. At Bolton Castle we find the chimneys in the walls; but, perhaps, those at Conway and Kenilworth are earlier proof of the alteration. The roofs with which some of these halls are spanned exhibit mechanical and artistic skill of the first order. The thrust, by the simplest means, is thrown comparatively low down in the best examples, so as to lessen the horizontal effect against the walls, and thus dispense with considerable solidity in the buttresses. *Fig.* 196. is a section of the celebrated Hall of Westminster, by which our observation will be better understood. These roofs were framed of oak or chesnut. Whether, when of the latter, it was imported from Portugal and Castile, is a question that has been discussed, but not determined, by antiquaries. Large stone corbels and projecting consoles were attached to the side walls, and were disposed in bays called *severeys* between each window. Upon their ends, demi-angels were generally carved, clasping a large escochion to their breasts. Near to the high table, a projecting or bay window, termed an *oriel*, was introduced. It was fully glazed, frequently containing stained glass of the arms of the family and its alliances. Here was the standing cupboard which contained the plain and parcel-gilt plate. The *rere-dos* was a sort of framed canopy hung with tapestry, and fixed behind the sovereign or chieftain. The walls were generally lined to about a third of their height with panelled oak or strained suits of tapestry. It was during this æra that privy chambers, parlours, and bowers found their way into the castle. Adjoining to, or nearly connected with the hall, a spacious room, generally with a bay window, looking on to the quadrangle, was planned as a receiving-room for the guests, as well before dinner as after. This was decorated with the richest tapestry and cushions embroidered by the ladies, and was distinguished by the name of the *presence* or *privy-chamber*. The females of the family had another similar apartment, in which their time was passed in domestic occupations and amusements. This last room was called *my lady's bower* or *parlour*, and here she received her visitors. Bay windows were never used in outer walls, and seldom others, excepting those of the narrowest shape.

416. The dawn of improvement in our domestic architecture opened in the latter part of the period, during which also brick came very much into use in England as a building material. " Michael de la Pole," as we learn from Leland's *Itinerary*, " marchant of Hull, came into such high favour with King Richard II. that he got many privileges for the towne. And in hys tyme the toune was wonderfully augmented yn building, and was enclosyd with ditches, and the waul begun; and in continuance endid, and made all of brike, as most part of the houses at that time was. In the waul be four principal gates of brike." After

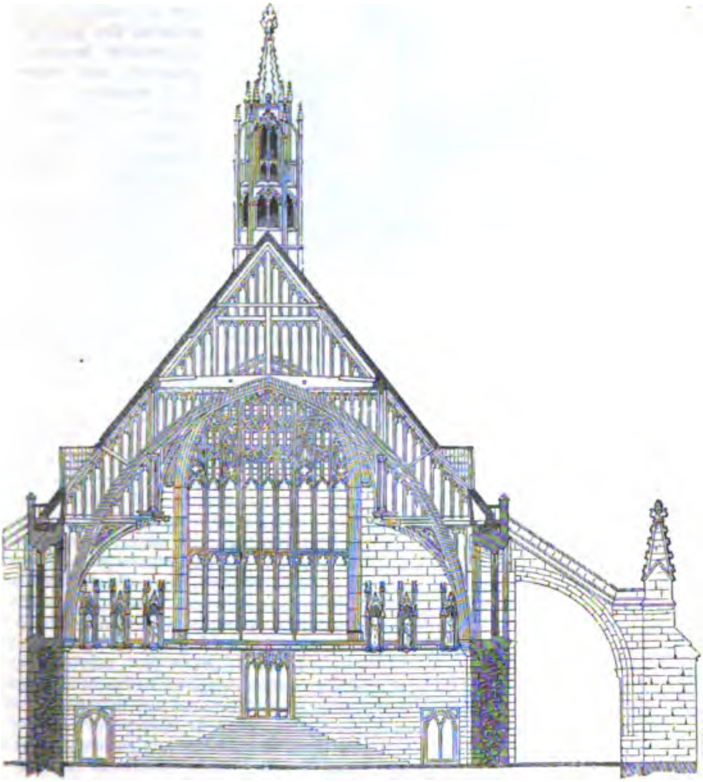


Fig. 196. SECTION OF WESTMINSTER HALL.

enumerating twenty-five towers, " M. de la Pole," we find from Leland, " buildid a goodlie house of brike, against the west end of St. Marye's churche, lyke a palace, with goodly orcharde and garden at large, also three houses besides, every on of which hath a tower of brik." (*Itin.* vol. i. p. 57.) This was the first instance of so large an application of brick in England.

417. One of the most important parts of the castle was the great gateway of entrance, in which were combined, at the same time, the chief elements of architectural beauty and military defence. It usually occupied the central part of the screen wall, which had the aspect whence the castle could be most conveniently approached. Two or more lofty towers flanked either side, the whole being deeply corbelled; a mode of building brought by the Arabs into Europe, and afterwards adopted by the Lombards and Normans. The corbel is a projecting stone, the back part whereof, which lies in the wall, being balanced by the superincumbent mass, it is capable of supporting a parapet projecting beyond the face of the wall rising from the horizontal course laid immediately on the corbels, between which the said horizontal course was pierced for the purpose of enabling the besieged to drop missiles or molten metal on the heads of the assailants. The corbel is often carved with the head of a giant or monster, which thus seems attached to the walls. In John of Gaunt's entrance gateway at Lancaster, the arch is defended by overhanging corbels with pierced apertures between them, and on either side are two light watch-towers crested with battlements.

418. Of the military architecture of this time, a perfect idea may be obtained from the two remarkable towers of Warwick Castle (*fig.* 197.), which were erected (in 1395) by Thomas de Beauchamp Earl of Warwick. The taller one rises 105 ft. above its base, and is 38 ft. diameter, having five stories, which are separated from each other by groined ceilings. In the interior, the walls of the state chambers were painted; a practice introduced into England in the beginning of the thirteenth century; and they were

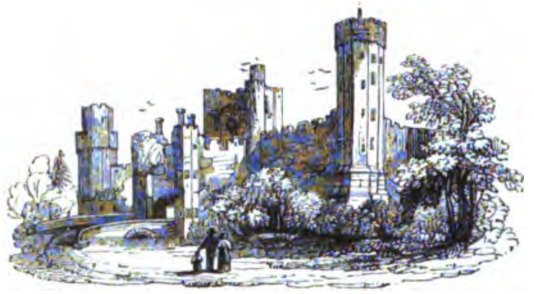


Fig. 197. WARWICK CASTLE.

sometimes lined with wainscot of curious carved *boisserie* on the panels, which afterwards became more adorned, and were hung with tapestry. At Warwick was a memorable suit of arras whereon were represented the achievements of the famous Guy Earl of Warwick.

419. The period of which we are treating was as celebrated for its bridge as for its military architecture, and exhibits as one of its examples that famed curiosity the triangularly formed bridge of Croyland in Lincolnshire, erected over the confluence of three streams. Bridge architecture was in many instances so necessarily connected with the construction of a fortress, that it may almost, in this age, be taken as a branch of military architecture.

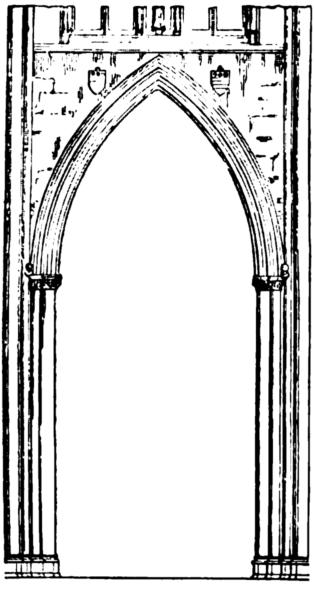


Fig. 198. ARCH OF YORK MINSTER.

420. This style exhibits *Arches*, less acute and more open (*fig.* 198. from York Minster), the forms varying. *Columns.* — The central and detached shafts now worked together into one, from experience of the weakness of those of the previous style, exceedingly various in their combinations. The *Windows* are larger, divided by mullions into several lights spreading and dividing at top into leaves, flowers, fans, wheels, and fanciful forms of endless variety. These marks are constant, but in the proportionate breadth there is much variation, for after having expanded in the reigns of Edward I. and II., they grew narrower again in proportion to their height in that of Edward III. and also sharper. The head was then formed of lines just perceptibly curved, sometimes even by two straight lines, sometimes just curved a little above the haunches, and then rectilinear to the apex. Eastern and western windows very lofty and ample, and splendidly decorated with painted glass. *Roof or Ceiling.* — The vaulting more decorated. The principal ribs spread from their imposts running over the vault like tracery, or rather with transoms divided into many angular compartments, and ornamented at the angles with heads, orbs, historical or legendary pictures, &c., elaborately coloured and gilded. *Ornaments.* — More various and laboured, but not so elegant and graceful in character, as in the preceding style. Niches and tabernacles with statues in great abundance. Tiers of small ornamental arches are frequent. The pinnacles are neither so lofty nor tapering, but are more richly decorated with leaves, crockets, &c. Sculpture is introduced in much profusion, and is frequently painted and gilt. Screens, stalls, doors, pannelled ceilings, and other ornaments, in carved and painted wood.

421. The principal examples of the ornamented English style in cathedral churches, are at *Exeter*, the nave and choir. *Lichfield*, uniformly. At *Lincoln*, the additions to the central tower. At *Worcester*, the nave. *York*, nave, choir, and western front. At *Canterbury*, transept. At *Gloucester*, transept and cloisters begun. *Norwich*, the spire and tower. *Salisbury*, spire and additions. *Bristol*, the nave and choir. *Chichester*, the spire and choir. *Ely*, Our Lady's Chapel and the central louvre. *Hereford*, the chapter-house and cloisters, now destroyed. In the later part of the period, the choir at *Gloucester*; the nave at *Canterbury* Bishop Beckington's additions at *Wells*, and from the upper transept to the great east window at *Lincoln*. In conventual churches, for the earlier part of the period, the western façade of *Howden* (1320.), *Chapel of Merton College, Oxford. Gisborne Priory*, Yorkshire. *Chapel at New College, Oxford. St. Stephen's Chapel*, Westminster. The additions to the pediments of the choir at *Kirkstall*, Yorkshire. *St. Mary's* in York. *Kirkham* in Yorkshire, and the *choir of Selby*, in the same county. For the later part of

the period, at *Tewkesbury*, the choir. At *Ely Cathedral*, *St. Mary's Chapel*. *Croyland façade* in Lincolnshire. *Beverley Minster* in Yorkshire. *Chapel of Magdalen College*, Oxford. *Eton College Chapel*, Bucks. *Chapel on the Bridge at Wakefield* in Yorkshire, built by Edward IV. in memory of his father Edward Duke of York; and the *Beauchamp Chapel* at Warwick. In parochial churches, for the early part of the period, examples may be referred to at *Grantham*, Lincolnshire. *Attelborough*, Norfolk. *Higham Ferrers*, Northamptonshire. *St. Michael*, Coventry. *Truro*, Cornwall. *Witney*, Oxfordshire. *Stratford-upon-Avon*, Warwickshire. *St. Peter Mancroft*, Norwich. *Boston*, Lincolnshire; its remarkable lantern tower, which is 262 ft. high, was begun in 1309, and was in progress of execution during the whole reign of Edward III. The expense of it having been chiefly defrayed by the merchants of the Hanse Towns. *St. Mary*, *Edmunds Bury*, Suffolk. *Maidstone*, Kent; and *Ludlow*, Salop. For the later part of the period, *St. Mary Overy*, Southwark. *Thaxted* and *Saffron Walden*, Essex. *Lowth* and *Stamford*, Lincolnshire. *Campden*, Gloucestershire. *St. Mary Redcliff* and the *tower of St. Stephen*, Bristol. *Taunton* and *Churton Mendip*, Somersetshire. *Lavenham*, Suffolk. *Manchester College*. *St. Mary's*, Oxford. *Whittlesea*, Cambridgeshire. *Wakefield*, Yorkshire. *Doncaster*, Yorkshire. *Newark-upon-Trent*. *Heckington*, Lincolnshire. *Mould Gresford* and *Wrexham* in Flintshire. *Melton Mowbray*, Leicestershire. *Octangular towers of St. Margaret's*, Norwich, and *All Saints*, York.

Sect. V.

FLORID ENGLISH OR TUDOR STYLE.

422. "There is," as Dr. Henry observes, "a certain perfection in art to which human genius may aspire with success, but beyond which, it is the apprehension of many, that improvement degenerates into false taste and fantastic refinement. The rude simplicity of Saxon architecture was (ultimately) supplanted by the magnificence of the ornamental Gothic; but magnificence itself is at last exhausted, and it terminated during the present period in a style, which some, with an allusion to literature, denominate 'the Florid.' It is a style censurable as too ornamental, departing from the grandeur peculiar to the Gothic, without acquiring proportional elegance; yet its intricate and redundant decorations are well calculated to rivet the eye, and amaze, perhaps bewilder, the mind." The period of the style is from 1460, to the dissolution of the religious houses in 1537, and comprehends, therefore, the reigns of Edward IV. and V., Richard III., Henrys VII. and VIII.

423. The ecclesiastical buildings of this æra are few. Somersetshire, a county devoted to the cause of the House of Lancaster, from the gratitude or policy of Henry VII., boasts perhaps more churches than any other county in the florid style; still they are very few, and the superb chapel which that monarch erected at Westminster is the best specimen that can be adduced for giving the reader a proper and correct idea of the Florid or Tudor style. There is doubtless an abundance of examples in oratories, porches, and small chapels, sepulchral sacella and the like; but beyond them we could cite very few entire sacred buildings; and those will be hereafter appended to this section as in the preceding ones. In civil, or rather domestic architecture, the case was far different: a very great change took place; and we shall endeavour to place a succinct account of it from the Rev. Mr. Dallaway's work, to which we have already been much indebted. The fifteenth century exhibits to us a number of vast mansions of the noble and opulent, wherein the characteristic style of the immediately preceding castles was not entirely abandoned, but superseded and mixed up with a new and peculiar one. The household books of the nobility which have come to our knowledge, indicate a multitudinous set of servants and retainers, for the reception of whom a great area of ground must have been covered, and in which provision, by the number of apartments, was made for a noble display of hospitality. This circumstance, of course, induced a gorgeous style peculiar to the earlier Tudor æra, of most of whose splendid mansions no memorial now exists but in the records of the times. But for the purpose of bringing a view of the whole subject under the eye of the reader, a brief recapitulation will here be necessary. The first palace of the Norman kings was the Tower of London, which was a strictly military residence. At Westminster was a palace of William Rufus, to whom Westminster Hall owes its original foundation. At Oxford a palace was built by Henry I., and at that place he kept his Christmas in 1115, as in 1229 and 1267 Henry III. did in the vicinity at Woodstock. It was at this place that Henry II. built a house of retirement, which has furnished the subject of some well-known legends. Henry III. is said to have refounded the palace at Westminster, which was much enlarged by Edward III. This, from the time of Rufus, its founder, to the reign of Richard II., to whom it owed its completion in the state apartments, with its magnificent hall and bijou of a chapel (St. Stephen's), had attained a greater extent than any contem-

porary palace in Europe. Edward III., besides erecting his suburban palace at Kennington, had re-edified and greatly extended Windsor Castle as a habitable fortification. Henry IV. inherited John of Gaunt's castle of Kenilworth and the Savoy in London, to both of which he made great additions. His gallant and victorious son was too much occupied with his military affairs to pay much attention to such matters; but many of his commanders, by the exorbitant ransoms they exacted of their French prisoners, were enabled to construct mansions of vast extent in those counties where their revenues commanded influence. Of these, as signal examples, may be cited Hampton Court in Herefordshire by Sir Rowland Lenthal; and Ampthill, Bedfordshire, by Sir John Cornwal Lord Tanhope. At Greenwich, a palace of great beauty, in the early part of the reign of Henry VI., was built by the regent Humphrey Duke of Gloucester, which, from its superiority over others, was by its founder called *Placentia* or *Plaisance.* This was completed by Edward IV., and is now remembered as the birthplace of Queen Elizabeth. The Lord Treasurer Cromwell expended a large sum on his residence at Tattershall in Lincolnshire, and at Wingfield Manor in Derbyshire, as did Lord Say and Sele, and Lord Boteler, respectively, at Sudley in Gloucestershire, and Hurstmonceaux in Sussex, all of which are now either destroyed or only in ruins. Additions were made by Edward IV. to Nottingham Castle, and by his brother Richard III. to Warwick Castle and that of Middleburg in Yorkshire.

424. Upon the establishment of the Tudor dynasty, Henry VII., on the ruins of a former palace at Shene in Surrey, which after the repairs he bestowed upon it was destroyed by fire, built a palace, whereto he gave the name of *Richmond,* in allusion to his former title, a name which was afterwards given to the beautiful town on the Thames, in its vicinity. The dimensions of the state apartments in this splendid building, whereof not a vestige now remains, are to be found in the Survey of 1649, when it was offered for sale by the Commissioners of Parliament. They abounded with bay windows of capricious formation, with rectangular and semicircular projections, producing a picturesque effect; and to add to its fantastic appearance, there were many octangular towers, surmounted with cupolas of the same plan, whose mitres as they rose were fringed with rich crockets. They were bulbous in their general form, thus bearing a resemblance in contour to the royal crown of the period.

425. The Tudor style, in domestic architecture, is thus divided by Mr. Dallaway. "1. That just alluded to; 2. The variations under Henry VIII.; 3. The Elizabethan style" (which will form a separate section), "as it admitted of Italian ornament in the designs of John of Padua and his followers, until the time of Inigo Jones.

426. The reign of Henry VIII. supplies numberless instances of the gorgeous expense to which the nobility and gentry proceeded in the productions of our art. The example set by the monarch himself was witnessed in no less than two royal mansions, each large enough to contain his numerous retinue. The following are the palaces that were built or repaired by Henry VIII.: —

1. Beaulieu, or Newhall, Essex.
2. Hunsdon, Herts, originally built by Sir John Oldhall, temp. Edw. IV
3. Ampthill, Bedfordshire.
4. Nonsuch, Surrey.
5. York Place, Whitehall, Westminster.
6. Bridewell and Blackfriars, London, for the reception of the emperor Charles V.
7. St. James's, Westminster.
8. Kimbolton, Huntingdonshire, the jointure of the divorced Queen Catharine of Arragon.
9. Sheriff Hutton, Yorkshire, given for the residence of Henry Duke of Richmond, the king's natural son.
10. King's Langley, Herts.

It was natural that the courtiers of such a monarch should vie with each other in erecting sumptuous houses in the provinces where they were seated. Wolsey, besides the progress he had made, at the time of his fall, in his colleges at Christchurch, Oxford, and Ipswich, had completed Hampton Court, and rebuilt the episcopal residences of York House (afterwards Whitehall), and Esher in Surrey. Edward Stafford, Duke of Buckingham, in his palace at Thornbury, Gloucestershire, almost rivalled the cardinal, and perhaps might have done so entirely if he had not been hurried to the scaffold before his mansion was completed. Grimsthorpe, in Lincolnshire, rose under the orders of the Duke of Suffolk (Charles Brandon). The Duke of Norfolk and his accomplished son, the Earl of Surrey, were, as appears from the descriptions of Kenninghall, Norfolk, and Mount Surrey, near Norwich, magnificent in the mansions they required for their occupation. We shall merely add the following list (which might, if it were necessary, be much augmented) of some other mansions of note. They are — 1. Haddon Hall, Derbyshire. 2. Cowdray, Sussex, destroyed by fire in 1793. 3. Hewer Castle, Kent. 4. Gosfield Hall, Essex, perfect. 5. Hengreave Hall, Suffolk, perfect, and whereof a beautiful work has been published by John Gage, Esq. (now Rookwode), a descendant of its ancient possessors. 6. Layer Marney, Essex, now in ruins. 7. Raglan Castle, Monmouthshire, in ruins. 8. Hunsdon House, Herts, rebuilt. 9. South Wingfield, Derbyshire, dilapidated. 10. Hill Hall, Essex, built by Sir Thomas Smyth, in 1542. 11. Wolterton (see *fig.* 199.)

in East Barsham, Norfolk, in ruins. 12. Harlaxton, Lincolnshire, perfect. 13. Westwood, Worcestershire, perfect.

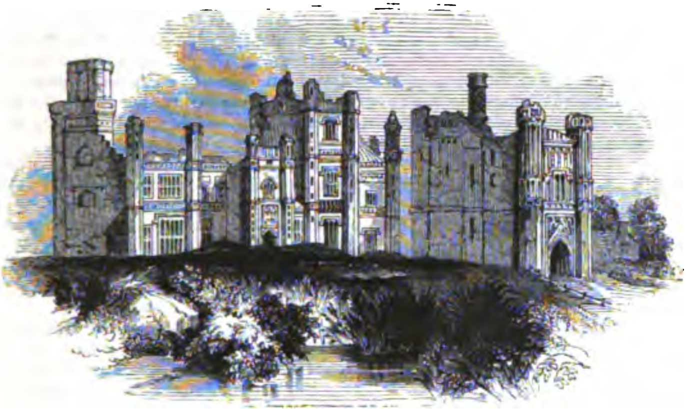


Fig. 199. WOLTERTON HOUSE.

427. In a very curious tract, entitled, "A Dyetorie or Regiment of Health," by Andrew Boorde, of Physike Doctor, 8vo., first printed in 1547, the following directions are given how a man should build his house or mansion; from which it appears that there were certain leading points for the guidance of the architect, founded, of course, they were on the habits of the time. "Make," says our friend Andrew, "the hall of such fashion that the parlor be annexed to the head of the hall, and the buttyre and pantrye at the lower ende thereof; the cellar under the pantrye sett somewhat at a base; the kechyn sett somewhat at a base from the buttrye and pantrye; coming with an entrie within, by the wall of the buttrie; the pastrie house and the larder annexed to the kechyn. Then divyde the logginges by the circuit of the quadrivial courte, and let the gatehouse be opposite, or against the hall doore; not directly, but the hall doore standyng abase of the gatehouse, in the middle of the front enteringe into the place. Let the prevye chamber be annexed to the great chamber of estate, with other chambers necessary for the buildinge; so that many of the chambers may have a prospecte into the chapell." Some of the principal innovations in the early Tudor style, were the introduction of gatehouses, bay windows, and quadrangular areas, matters rather incompatible with buildings constructed for defence. The materials of these palaces and mansions were of freestone and brick, according to the facility with which from the situation they could be procured. Sometimes, indeed often, these materials were mixed. Moulded brickwork and terra cotta were introduced for ornamental parts by Trevigi and Holbein towards the end of the period, or, perhaps strictly speaking, at the end of it. The brickwork was occasionally plastered and pointed as at Nonsuch. At Layer Marney and other places, bricks of two colours highly glazed were used for variegating the surface, and were formed into lozenges. The chimney shafts seem to have exhausted invention in the twisted and diapered patterns into which they were wrought, and decorated with heads and capitals and cognizances of the founders. The gateways were prominent features in these edifices, and the most expensive ornaments were lavished on them. That at Whitehall, designed by Holbein, was constructed with differently coloured glazed bricks, over which were appended four large circular medallions of busts, still preserved at Hatfield Peveril, Herts. This gateway contained several apartments, among which not the least remarkable was the study wherein Holbein chiefly received his sitters. The gateways at Hampton Court and Woolterton were very similar to this.

428. We will here digress a little on the bay window which, as generally understood, was simply a projecting window between two buttresses (whence its name, as occupying a bay of the building), and almost universally placed at the end of the room. It was invented about a century before the Tudor age, in which it usually consisted on the plan of right angles intersected by circles, as in the buildings at Windsor by Henry VIII., and at Thornbury Castle. When placed at the end of a great hall, it extended in height from the floor to the ceiling, and was very simple and regular in its form. In a MS. at the Herald's College relating to an entertainment given at Richmond by Henry VII., the following passage occurs, and may be taken as descriptive of one of the purposes to which it was applied. "Agaynst that his grace had supped: the hall was dressed and goodlie to be seene, and a rich cupboord sett thereup in a baye window of IX or X stages and haunces of hight, furnissed and fulfilled with plate of gold, silver, and regilte." Carved wainscotting in

panels, generally of oak, lined the lower part of the halls with greater unity of design and execution than heretofore; and it now found its way into parlours and presence chambers with every variety of cyphers, cognizances, chimeras, and mottoes, which in the castles of France about the age of Francis I. were called *Boisseries*. Of these some curious specimens still remain in the hall and chambers of the dilapidated mansion of the Lords de La Warre at Halnacre in Suffolk. The area or court was quadrangular, and besides the great staircase near the hall, there were generally hexangular towers containing others: indeed, they were usually to be found in each angle of the great court, rising above the parapets, imparting a pleasant and picturesque effect to the mass of building, and grouping well with the lofty and ornamented chimneys of which we have above spoken.

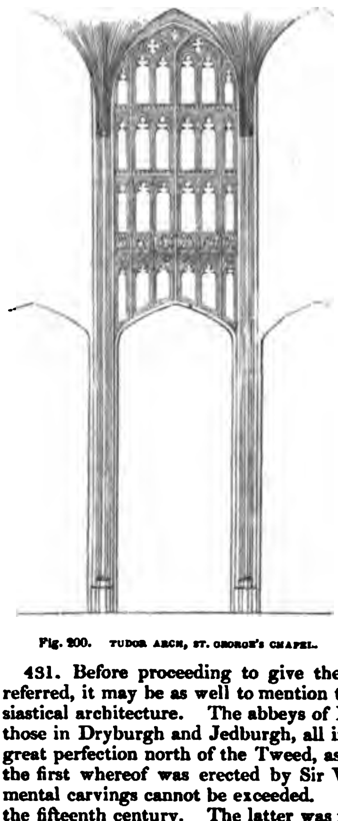


Fig. 200. TUDOR ARCH, ST. GEORGE'S CHAPEL.

429. It is melancholy to reflect upon the disappearance of these mansions which were once the ornaments of the provinces, and now one by one falling fast away by the joint operation of what is called repair and by decay. Most of their remains have been removed to raise or to be incorporated with other buildings for which they might have well been spared.

430. The characteristics of the style are *arches*, universally flat, and wide in proportion to their height (*fig.* 200.). *Windows*, much more open than in the last period, flatter at the top, and divided in the upper part by transoms, which are almost constantly crowned with embattled work in miniature. The *ceilings* or vaultings spread out into such a variety of parts, that the whole surface appears covered with a web of delicate sculpture or embroidery thrown over it; and from different intersections of this ribbed work, clusters of pendant ornaments hang down, as Mr. Millers observes, like "stalactites in caverns." The *flying buttresses* are equally ornamented, and the external surfaces of the walls are one mass of delicate sculpture. The *ornaments*, as may be deduced from the above particulars, are lavish and profuse in the highest degree. Fretwork, figures of men and animals, niches and tabernacles, accompanied with canopies, pedestals, and traceries of the most exquisite workmanship, carried this style to the summit of splendour; and all these combined, had, perhaps, no small share in producing the extinction it was doomed to undergo.

431. Before proceeding to give the examples in this style, to which the reader will be referred, it may be as well to mention that Scotland boasts of many fine specimens of ecclesiastical architecture. The abbeys of Melrose and Kelso, founded by David I., as well as those in Dryburgh and Jedburgh, all in Roxburghshire, prove that the art advanced to as great perfection north of the Tweed, as it did in England. Roslin and Holyrood chapels, the first whereof was erected by Sir William St. Clair, for richness and variety of ornamental carvings cannot be exceeded. Its plan is without parallel in any other specimen of the fifteenth century. The latter was finished by James, the second of that name, in 1440, and is a beautiful example with flying buttresses, which are more ornamented than any even in England.

432. Examples of the Florid Gothic or Tudor style are to be seen at the cathedral churches — of *Gloucester*, in the chapel of Our Lady; at *Oxford*, in the roof of the choir; at *Ely*, in Alcock's chapel; at *Peterborough*, in Our Lady's chapel, and at *Hereford*, in the north porch. In conventual churches, at *Windsor*, St. George's chapel; at *Cambridge*, King's College chapel; at *Westminster*, King Henry VII.'s chapel; at *Great Malvern*, in Worcestershire, the tower and choir; at *Christ Church*, Oxford, the roof of the choir, and at *Evesham Abbey*, in Worcestershire, the campanile and gateway.

433. For parochial churches, except in some very few specimens in Somersetshire, and there perhaps only in parts, we are unable to refer the reader to a complete specimen, in all its parts, of the Tudor style. The pulpit and screen at Dartmouth, in Devonshire, are worthy of his notice.

434. We shall close this section by a tabular view of the founders and dimensions of the different cathedrals of England, extracted from Dallaway and other authors.

BATH — Conventual Church of the Benedictines.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
		L. B. H.	L. B. H.	L. B. H.	L. B. H.	L. B. H.
1495 to 1502	Oliver King, bishop -	-	75 35 73	-	46 48 74	20 30 150
1532	Bird Gibbes priors -	136 72 78	-	Of the nave. 112 21 38	46 28 74	
1570	Inhabitants of Bath Sir John Harrington and others -	-	-	Of the choir. 80 21 38		
1609	James Montague, bishop	Completed the building				

Building unfinished at the Reformation, and completed by Bishop Montague and the executors of the Lord Treasurer Burleigh. Total length, 210 ft.; breadth, 126 ft.

BRISTOL — Conventual Church of St. Augustine.

Dates:	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower
		L. B. H.	L. B. H.	L. B. H.	L. B. H.	Height.
1160	Robert Fitzharding					
1230 1311 to 1332	Robert third Lord Berkeley, Maurice fourth Lord Berkeley, and Edmund Knowles, abbot -	75 73 43	Originally included.		128 - 43	-
1463	Elliot and William Hunt, abbots -	-	100 - 43	-	N. trans.	127
1481 to 1500	John Newland, abbot, completed - -	-	Our Lady's Chapel.			

The church displays two distinct styles. The Chapter House and Elder Lady Chapel were erected at the beginning and close of the twelfth century, and the existing nave and choir in the beginning of the fourteenth. It is probable it was not completed after the plan of the Abbot Knoles. The tower was intended to receive a spire. The aisles and nave are of the same height, which is only 43 ft.

CANTERBURY — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Towers.
		L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1070	Archbishop Lanfranc	-	-	-	-	N.W. 100 ft.
1090	Archbishop Anselme					
1100	Ernalphus Conrade priors -	The second church destroyed by fire in 1174.				
1122	Archbishop W. Corboil.					
1174	W. Senensis W. Anglus architects	Present church.	150 40 71	Included	Upper 1	
1304	Henry de Estrey, prior.					
1379 to 1431	S. Sudbury W. Courtenay T. Arundel archbishops	Improved and ornamented.	-	-	Lower 124	N.W. spire of lead added 100 ft. high; taken down 1705; S.W. 130 ft.
1449	T. Chittenden T. Goldstone priors	214 94 80				
1468	W. Sellinge.					
1490	W. Morton, archbishop	-	-	-	-	Central 234 high, 35 diameter.

The original Anglo-Saxon structure of Lanfranc was rebuilt after the canonisation of Thomas à Becket. The very elegant central tower was completed in 1500 by Archbishop Morton. This cathedral has a lofty crypt of greater extent than, we believe, any other in England. At the eastern end of this cathedral, and projecting eastward of the general line of the plan, is an apartment open to the rest of the church, and consisting of a segment equal to about three fourths of a circle, called "Becket's Crown." The internal length of this church is 514 ft., and breadth 154 ft.

CARLISLE — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Towers.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	Height.
1150 1270	Henry Murdac, abbot of Fountains -	82 – 71 Originally164	-	Included.		
1353 to 1363	Gilbert de Wilton, bishop - -	-	137 – 71	71 – –	124 28 71	
1363 to 1397	T. de Apylby - -					
1400 to 1419	Z. de Strickland -	-	-	-	-	128 ft.

The total length, 219 ft.; breadth, 124 ft.

CHESTER — Conventual Church of Benedictines.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
		L. B. H.	L. B. H.	L. B. H.	L. B. H.	Height.
1128	Ranulf Earl of Chester					
1320	- - -	-	-	-	Transept dissimilar. North, a parish church. 180 – –	
1485	Simon Ripley, abbot —— Oldham, abbot	– 73 73	-	-	-	127 ft.
1508	- - -	The western front	-	-	-	Finished in 1508.

The Chapter House was built by Ranulf Earl of Chester, and in it many of his descendants are interred. A north transept only in this church. Length, 348 ft.; breadth, 180 ft.

CHICHESTER — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1094	Ralph - - -	First church.				
1125	Siffrede - - Abbot of Glastonbury	105 95 61	-	Included – 91 –		
1217	Ralph de Warham -	-	100 64 61	There are four aisles. The only instance in England.	North	95 ft. high W. end.
1282	Gilbert de St. Leofard					
1329	John de Langton -	-	-	-	South, with window.	107 ft. high bell tower; spire added to tower 271 ft. high.
1520	Robert Sherbourne -	Repairs and embellishment of the choir, &c.				

It may be right to consider the present church as founded by Siffrede upon that built by Ralph in 1094. Total length, 407 ft.; width, 131 ft.

DURHAM — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1093	William de Carilelpho -	260 74 69				
1128	Ralph Flambard.					
1230	Richard Poose and -	-	-	Included.	176 57 –	
1233	Melsonby, prior -	-	-	-	-	Western towers 143 ft.
	Bertram Middleton, and Hugh Darlington, priors - -	-	120 74 71	-	90 18 –	
	Nicholas de Farnham, bishop.					
1295	Richard de Houton, prior - -	-	-	-	-	Central tower 214.

The Lady Chapel was built in 1390, forming a sort of transept at the end of the choir. This cathedral is remarkable from the pillars of its nave, which are curiously striated. The Galilee, or chapel, at the western end, is 50 ft. by 78 ft., and was finished by Bishop Langley in 1430. Total length of the church, 420 ft.; width, 176 ft.

ELY — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	Length.	
1109 to 1133	Herney - -	-	-	-	N. 178½	
	Nigillus - -	Erected the cloisters.				
1174	Id. Geoff. Ridal -	203 - 104	-	-	-	Centre of West front 210 ft. high.
1235 to 1252	Hugh Northwold -	-	Presbytery, which was made the choir in 1769.			
1337	Simon Montacute -	-	Octagon Louvre.			
	I. Wisbich, prior -	-	101 34½ 70			

A spire of wood was added to the tower by Bishop Northwold, but it no longer exists. The octagon, from which rises the louvre, is 142 ft. high from the floor, and is 71 ft. 6 in. diameter. It was designed by Alan de Walsingham, a monk of Ely, in 1328. The diameter of the lantern is 30 ft., and its external height 170 ft. Total length, 517 ft.; breadth, 178 ft. 6 in.

EXETER — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	L. B. H.
1100 to 1128	W. Warlewast - -	-	-	-	-	28 28 145
1280 to 1293	Peter Quivil - -	-	-	-	140 32 68	
1293 to 1307	Thomas Bytton - -	180 40 68	-	148 20 35		
1307 to 1318	Walter Stapylton -	-	132 34 68	132 20 35		
1340	Edmund Lacy - -	Built the chapter house.				

The cloisters, which are only perfect on one side, were added by Thomas Brentinghan. The towers stand at the ends of the transept. The general plan of the church is that designed by Bishop Quivil, from which none of his successors deviated. The total length is 390 ft.; width, 140 ft. Bishop Grandison's screen in this cathedral is celebrated among antiquaries as displaying a series of statues more numerous and entire than are to be found in any other cathedral.

GLOUCESTER — Conventual Church of Benedictines.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
		L. B. H.	L. B. H.	L. B. H.	L. B. H.	L. B. H.
1057 to 1089	Aldred, Bishop of Worcester -	171 41 67½				
1089	Id. - - -	-	-	N. 171 21 40½		
1310	Abbot, J. Thokey	-	-	S. 171 22 –		
1330	Abbot, J. Wygmore	-	-	-	S. 66 43½ 78	
1330 to 1357	Adam Staunton to Walter Frocester, and to Thomas Sebroke - -	Clerestory and vaulting.	140 34½ 86			
1369 to 1375	Ut supra - -	-	-	-	N. 66 43½ 78	
1457 to 1518	W. Ferleigh to Thomas Bramish, and to W. Parker -	-	-	-	-	24 22 224

The Lady Chapel was built by W. Ferleigh about 1498. The western façade and two arches were added to the nave about 1370 by T. Horton. The tower rises from the intersection of the nave and choir with the transepts. The cloisters are the most perfect and beautiful of any in England, and are unusually situated, being on the north side of the church. Total length, 426 ft.; width, 152 ft.

HEREFORD — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1079 to 1095	Robert de Losinge -	144 68 68	-	144 – –	140 – –	
1101 to 1115	Rainelm - -	-	125 20 64			
1131 to 1148	Robert de Bethune, prior of Llanthony	-	-	-	Lower. 111 – –	Ancient spire 240 ft. high.
1200 to 1216	Giles de Bruse -	-	-	-	-	West tower was 130 ft.
1492 to 1502	Edmund Audley -	-	-	-	-	The spire, which was taken down in 1790.
		Restored in 1786.				

The great west tower fell in 1786, and destroyed the greater part of the nave and aisles, which were rebuilt shorter by 15 ft. The architecture of the chapter house, which was octagonal, with a single central pillar, and 37 ft. diameter, was unnecessarily taken down by Bishop Egerton. Total length, 325 ft.; width 100 ft.

LICHFIELD — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1295 to 1430	Walter de Louton, or Langton - - And his successors -	213 67 67	120 33 67	Included.	88 – –	West spires 183 ft. high.
	William Hewworth, who died in 1447	W. front. 78 – –	-	-	-	Total of the central spire. 258.

The church is very uniform, having been, like Salisbury and Exeter, completed upon one plan. The arches in the Triforia here show the dog-tooth moulding in great perfection. Total length, 411 ft.; breadth, 88 ft.

LINCOLN — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Towers and Spires.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1184	Alexander Normannus - -	Rebuilt.				
1186 to 1200	Hugh de Grenoble	240 80 80	140 40 72	Included.		
1240	Robert Grostête					
1254	Henry Lexington -	-	-	-	-	Central 288 ft. high W. 260 ft.
1286 to 1300	Hugh Burgundus	-	Presbytery.	-	W. 220 63 74	W. fron 173 ft. wide 83 ft. high.
1306	John D'Alderby -	-	106 82 72	-	E. 166 63 72	
1438	William Alnewick -	Built the great west window and porch.				

The central spire of this cathedral was higher than that of Salisbury, and was blown down in 1547. The others were removed in 1808. Total length, 498 ft.; breadth, 227 ft.

LONDON — Old St. Paul's Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Towers.
	Bishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1086	Mauritius - -	335 91 102				
1120	Richard de Beaumes -	-	-	Included.	297 - -	
1220	William de St. Maria -	-	163 - 88	-	-	Height 260 ft., ditto of spire 274 ft. Burnt down in 1561.

The Chapter House was built by William de St. Maria, and was octangular. The cloisters, which were only 91 ft. square, were erected by Henry de Wingham in 1260; and the Lady Chapel by Henry de Lacy, Earl of Lincoln, in 1312. The area which this cathedral covered in 1309 was 3 acres, 3 roods, and 26 perches. The cloisters were removed by the Protector Somerset, to build his palace in the Strand. Inigo Jones commenced his restorations upon the fabric in 1633, and placed, in 1636, a most beautiful but incongruous Corinthian portico at the western end, the expense of which was borne by Charles I. The whole of the church was taken down and removed by Sir Christopher Wren in 1675. The following are the dimensions assigned to the cathedral in 1309:—Length, 681 ft.; breadth, 130. The height of the vaulting of the western part, 102 ft.; of the eastern, 188 ft.: of the tower, 260 ft.: and of the spire, which was timber-framed and covered with lead, 274 ft. Dugdale's history of the church is embellished with numerous plates by Hollar, and is a most interesting work.

NORWICH — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.		L. B. H.	
1096	Herbert Losinga -	-	-	-	-	Tower.
1171	Eborard - - -	140 71 -				
1197	John of Oxford - -	-	165 - -	Included.	191 - -	
1361	Ralph Walpole Thomas Percy -	-	-	-	-	Spire 317 ft.

This church has no Lady Chapel. The cathedral, before 1272, was so dilapidated, that it was nearly rebuilt by succeeding bishops and priors. The cloisters, erected by Bishop Wakering in 1420, are the most spacious in England, being 174 ft. square. Length of cathedral, 414 ft.; breadth, 191 ft.

OXFORD — Conventual Church of St. Frydeswide Aug. Canons.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
		L. B. H.	L. B. H.		L. B. H.	
1050 1120	Guymond, prior of St. Frydeswide	74 54 41½	80 37 -	Included.		
1122	- - - -	-	-	-	102 - -	Tower.
1528	Cardinal Wolsey -	-	-			
1545	Robert King, first bishop	-	Clerestory	-	-	Spire.

The Chapter House here is of perfect Anglo-Norman architecture, built in the reign of Henry II. Length of church, 154 ft.; breadth, 102 ft.

PETERBOROUGH — Conventual Church of the Benedictines.

Dates.	Founders.	Nave.			Choir.			Aisles.	Transept.			Tower.
		L.	B.	H.	L.	B.	H.		L.	B.	H.	
1160 tem. Hen. II.	William de Watteville, 21st abbot - -	-			138	78	78					
1175	Benedict, 22nd abbot -	231	78	–	-			Included.				
1272	Richard de London, 32nd abbot - -	-			-			-	203	69	78	
1295 1300	William de Parys, prior or W. de Woodford, abbot - - -	-			-			-	-			Two spires 156 ft. high.
1330	Geoffry Croyland, 34th abbot - -	-			-			-	-			Unfinished tower, 120 ft. Louvre, 150 ft.
1496	Robert Kirton, 44th abbot, built the chapels at the end of the choir.											

Length, 480 ft.; breadth, 203 ft.

ROCHESTER — Cathedral Church.

Dates.	Founders.	Nave.			Choir.			Aisles.	Transept.			Tower.
	Bishops.	L.	B.	H.	L.	B.	H.		L.	B.	H.	
1080	Gundulphus - -	150	75	–								
1115	Ernulph - - -	-			-			-	122	–	–	
1227	Henry Sanford - -	-			156	–	–	Included.	-			Spire, 156 ft.
1270	W. de Hoo, prior, built a chapter house.											

When the choir was rebuilt, in 1227, it was extended to a greater length by several feet than the nave itself. The choirs of Norman churches were all disproportionately short. Total length, 306 ft.; breadth, 122 ft.

SALISBURY — Cathedral Church.

Dates.	Founders.	Nave.			Choir.			Aisles.	Transept.			Tower.
	Bishops.	L.	B.	H.	L.	B.	H.		L.	B.	H.	
1217	Richard Poore - -	229	76	81	-			-	-			To the Parapet, 207 ft.
1230	Robert Bingham -	-			140	–	84	Included.				
1274	Robert Wykehampton	-			-			-	230	60	84	Spire, 404 ft.

This is the most uniform of the cathedrals of England. It was ascertained, in 1737, that the roof altogether contained 2641 tons of timber. According to the account delivered to Henry III., it appeared that 40,000 marks (22,666*l.* 13*s.* 4*d.*) had, up to that time, been expended on the fabric. The original plan was given by Bishop Poore, and from it no variation was made by his successors. The church was twice consecrated. The Chapter House is octangular, with a central column, and the cloisters are 160 ft. square. The spire is of masonry only 7 in. thick, and would hence seem to be scarcely adequate to support its own weight. The total length is 474 ft., and the western front is 112 ft. wide. Great repairs were made to it by Sir Christopher Wren.

WELLS — Cathedral Church.

Dates.	Founders.	Nave.			Choir.			Aisles.	Transept.			Tower.
	Bishops	L.	B.	H.	L.	B.	H.		L.	B.	H.	L. B. H
1205 to 1239	Josaline Troteman -	191	67	67	108	67	–	Included.	135	–	67	
1293	W. de March											
1366	John Harwell											
1450	Thomas Beckington -	-			-			-	-			Western. 234 - 130
1465	Robert Stillington -	-			-			-	-			Central. - - 160

This is a very extraordinary example. Its western façade is decorated with statues in a more perfect state than is seen in any cathedral excepting that of Lincoln. The subjects are kings, bishops, and warriors. The original plan seems to have been strictly followed to its completion by Bishop Stillington. Speed says that Ralph de Shrewsbury, who died in 1363, was a great benefactor to the church, and prosecuted the original plan. The support of the central tower is assisted by the principle of the inverted arch as at Salisbury, and is a good example of constructive skill. Total length, 371 ft.; breadth, 185 ft.

WESTMINSTER — Conventual Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
		L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1250	King Henry III. -	166 38 101	155 38 101	166 16 101		Height to the top of the western turrets, addition 102½ ft., 225 ft. in the whole
1300	King Edward I. -	Extreme breadth of the Nave and Aisles, - 71¾ -	-	-	136 40 78	
1490	King Henry VII. -	Chapel, 103 ft. long, 35 ft. broad, 60 ft. high; aisles, 62 ft. long, 17 ft. broad.				

The flying buttresses of Henry VII.'s chapel are among the most beautifully decorated in England. The triforia of the church are lighted from a range of windows in the back wall, which are seen externally, each consisting of three circles, inscribed within a triangle, equilaterally composed of three segments of circles. The architect was Thomas Fitz-Otho, the king's Master of the Mint.

WINCHESTER — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.		L. B. H.	
1070	Wakelyn - - -	-	-	-	186 – –	150 ft. high.
1190	Godfrey de Laci, the Cloisters					
1350	William de Edynton, the Lady Chapel					
1394	William de Wykeham -	300 86 78				
	Cardinal Beaufort -	-	Presbytery			
1493	T. Langton - -	-	93 86 78	Included.		

The western front was finished by Edynton. The nave, which was finished by William of Wykeham, is longer than that of York, and considered one of the finest in England. The exterior of the choir is of the finest Gothic of the fifteenth century. The choir, as at Gloucester, is under the tower. Total length, 545 ft.; breadth, 186 ft.

WORCESTER — Cathedral Church.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Bishops.	L. B. H.	L. B. H.		L. B. H.	
1218 to 1224	William de Blois -	212 78 72	80 36 61	Included.	Lower, 128 32 –	
1327	T. Cobham, Lady Chapel					
1372	W. de Lynne - -	-	-	-	-	172 ft. high.
1374 to 1380	Henry Wakefield -	-	-	-	Upper, 120 25 –	

The Chapter House here, a decagon 58 ft. diameter, and the cloisters, 120 ft. long and 125 ft. in breadth, were erected in the time of W. de Wynne. The original church was built before 1150, and parts of it may still be traced. The refectory of the convent, 120 ft. by 38 ft., is still perfect. The nave is, for style and proportions, well worthy the attention of the student. The total length of the church is 410 ft.; its breadth, 120 ft.

YORK — Cathedral.

Dates.	Founders.	Nave.	Choir.	Aisles.	Transept.	Tower.
	Archbishops.	L. B. H.	L. B. H.	L. B. H.	L. B. H.	
1227	Walter Grey - -	-	-	-	222 - 103	
1291	John Romain - -	250 103 92	-	250 - 47		
	W. de Melton - -	-		-	-	Façade and western towers 196 ft.
1361	J. Thoresby - -	-	150 43 101			
1300 to 1420	J. Birmingham, treasurer, completed the façade -	-	-	-	-	L. B. H. Central. 44 42 182

Octagonal Chapter House, erected by W. de Melton. The foundations of the church were laid in 1171, by Roger, then archbishop. The central lantern or steeple, built by Le Romain, was taken down in 1380 by Walter Skirlawe. The aisles surround the church in every part, are of similar dimensions, and were built at the same time. The open central tower, or louvre, is 188 ft. from the floor. The Rose Window, the finest in England, is 22 ft. 6 in. diameter. Total length, 498 ft.; breadth, 222 ft.

435. The following synoptical view of the general dimensions of the above cathedrals, we think, may prove occasionally useful to the reader, by enabling him to compare the whole of them and their parts with each other. The equality of the proportions is striking; and, in another part of this work, we hope to place before the reader some principles which tend to prove that there was a much more established practice founded on the laws of statics than has hitherto been conjectured. Dallaway, without the remotest idea of the principles in question, has observed, with his usual sagacity, that there appears in them "a distribution of parts which will hold almost generally, that the width of the nave is that of both the aisles, measured in the place to the extremity of the buttresses externally; and that the breadth and height of the whole building are equal. In the more ancient churches, the aisles are usually of the width of the space between the dividing arches." Some idea of the principle is conveyed in the plates of Milan cathedral, curiously introduced into the very early translation of *Vitruvius* by Cæsar Cesarianus, a work of great curiosity, and of which copies are now rarely met with.

A Synoptical View of the leading Dimensions of the English Cathedrals.

Cathedral.	Total internal Length.	Naves and Aisles.			Choirs.			Transepts	Spires and Towers.
		Length.	Breadth.	Height.	Length.	Breadth.	Height.	Breadth.	Height.
Winchester -	545	247	86	78	138	-	73	186	
Ely - -	517	327	73	70	101	73	70	178	Tower - - 210
Canterbury -	514	214	70	80	150	74	80	154	Do. - - 235
Old St. Paul's	500	335	91	102	165	42	88	248	Spire - - 534
York - -	498	264	109	99	131	-	99	222	Tower - - 234
Lincoln -	498	-	83	83	-	-	-	227	Do. - - 260
Westminster	489	130	96	101	152	-	151	189	
Peterborough	480	231	78	78	138	-	78	203	Louvre - - 150
Salisbury -	452	246	76	84	140	-	84	210	Spire - - 387
Durham -	420	-	-	-	117	33	71	176	Tower - - 214
Gloucester -	420	174	84	67	140	-	86	144	Do. - - 225
Lichfield -	411	213	67	-	110	-	67	-	Spire - 258 W. 183
Norwich -	411	230	71	-	165	-	-	191	Do. - - 317
Worcester -	410	212	78	-	126	-	74	130	Tower - - 196
Chichester .	401	205	91	61	100	-	-	131	Spire - - 267
Exeter - -	390	173	74	69	131	-	69	140	Tower - - 130
Wells - -	371	191	67	67	106	-	67	135	Do. - - 160
Hereford, anct.	370	144	68	68	105	-	64	140	
Chester - -	348	-	73	73	-	-	-	-	Tower - - 127
Rochester -	306	150	65	-	156	-	-	122	Spire - - 156
Carlisle -	213	-	71	71	137	71	-		
Bath - -	210	136	72	78	-	-	-	126	Tower - - 162
Bristol - -	175	100	75	73	100	-	-	128	Do. - - 127
Oxford -	154	74	54	41	80	-	37½	102	Spire - - 184

To the above we subjoin the correspondent dimensions of the several component parts of some of the cathedral churches enumerated, which we consider useful to the student as well as the general reader.

	Total Length.
Chichester cathedral church - -	410 ft.
Norwich cathedral church - - -	411
Worcester cathedral church - -	410
Durham cathedral church - - -	420
Gloucester conventual church - -	420

	Heights of Naves.	Style.
Salisbury cathedral church	84 feet	Pointed arch.
Lincoln cathedral church	83 —	Pointed arch.
Canterbury cathedral church	80 —	Pure Gothic.
Peterborough conventual church	78 —	Norman.
Winchester cathedral church	78 —	Pure Gothic.
Durham cathedral church	71 —	Norman.
Ely cathedral church	70 —	Norman.
Exeter cathedral church	69 —	Pointed arch.
Gloucester conventual church	67 —	Norman.
Wells cathedral church	67 —	Pointed arch.

Breadths of Naves and Aisles.

Norwich - 71 ft.

Bristol	73	Canterbury	74 ft.	Peterborough	78 ft.	Lincoln	83 ft.
Chester	73	Exeter	74	Worcester	78	Gloucester	84
Ely	73	Salisbury	76	Durham	80	Winchester	85

The author just quoted, in reference to the tables here given, says of them, that "the parallel will afford us, at one view, authentic information concerning the proportion of one constituent part to another of every cathedral in England which is worthy the notice of an architect. Such," he continues, "a coincidence of dimensions as that which is found in many of them, can scarcely be supposed to be the effect of chance, especially where the buildings are contemporary and of an exactly correspondent style." It appears that the equality of proportions is confined to each era and style of ecclesiastical architecture in so remarkable a degree as to lead us to conjecture that they might have been designed by the same architect. "The constant rivalry," says Dallaway, "which subsisted between the magnificent prelates, was excited upon the erection of any part of a cathedral of superior beauty, and imitated in those of the same kind which were then undertaken; and the architect who had once displayed great talents was invited to repeat the more perfect performance, upon which he had rested his professional fame." We have not considered it necessary to devote a special portion of our work to the conventual architecture of England, because it followed the style of the time. It was of great splendour. The ground plans of their habitable portions were usually, though not always, quadrangular, and in the later ages partook of the improvements in domestic architecture, as in the colleges built by Wykham and Waynflete, and many of the episcopal residences. Glastonbury and Reading presented exceedingly fine examples of it; the former comprised within its walls sixty acres of ground.

Sect. VI.

ELIZABETHAN ARCHITECTURE.

436. The revival of the arts in Italy has furnished the subject of Chap. II. Sect. XVI. It commenced, as we have there seen, with its author Brunelleschi, who died in 1444; and it was not till more than a century afterwards that, notwithstanding our constant intercourse with the Continent, its influence began to be felt in this country. The accession of Elizabeth, it will be recollected, took place in 1558.

437. Whilst the art was in the hands of the clergy, though here always, in point of time, behind that of the Continent, it flourished vigorously; but when that body was scattered by the dissolution of the religious houses, no one remained to foster it; and though Henry VIII. delighted in *spectacle*, and a gorgeous display of his wealth, he was far too great a sensualist to be capable of being trained to refinement in the arts. Neither, moreover, are the English, as a people, susceptible of high feeling in respect of the productions of art. Even to the present hour so low in the scale do they stand, that a lady's cap finds no adoption, receives no sanction among the higher classes, unless moulded and previously sanctioned in the capital of our lively neighbours. In short, the only period in which the arts seemed likely to take root here was under that unfortunate monarch Charles I.; since whose time they have languished, giving way to politics, which engross the attention of the higher class, and to commerce, which occupies the attention of the merchants. There is here no general pervading love of the arts, as among all classes on the Continent, though we believe the time for it approaches. The Elizabethan, or, as some have, perhaps more properly, called it, the last Tudor style, is an imperfectly understood adaptation of classic forms to the habits of its day in this country. It is full of redundant and unmeaning ornament, creating a restless feeling in the mind of the spectator, which, in the cinque cento work, the renaissance of Italy, was in some degree atoned for by excellence of design, by exquisite execution of the subject, and by a refinement in the forms which some of the first artists the world ever saw gave to its productions. In Italy, the orders almost

instantaneously rose in their proper proportions, soon leaving nothing to be desired; but in England they were for a long time engrafted on Gothic plans and forms, producing nothing but heterogeneous masses of absurdity. It was, nevertheless (strange to say), in this style and the Gothic, that the wisdom of the legislature thought proper to solicit designs from the architects of the country, in the year 1836, for new houses of Parliament, a proceeding which has excited the smiles of the artists of the Continent at our absurdity in matters of art.

438. The work of Andrew Borde has been before mentioned; but the earliest publication in England relative to practical architecture was, "The first and chiefe Grounds of Architecture used in all the ancient and famous Monyments, with a farther and more ample Discourse uppon the same than has hitherto been set forthe by any other. By John Shute, paynter and architecte." "Printed by John Marshe, fol., 1563." This John Shute had been sent by Dudley, Duke of Northumberland, to Italy, probably with the intention of afterwards employing him upon the works which he was projecting. From this and many other circumstances, it is easy to discover that domestic architecture under Elizabeth had assumed a more scientific character. Indeed, there is ample evidence that no building was now undertaken without the previous arrangement of a digested and regulated plan; for early in the reign of this sovereign the treatises of Lomazzo and Philibert de Lorme were translated into English; and in the construction of the palatial houses of the aristocracy, the architects had begun to act upon a system. The principal deviation from the *plans* of the earlier Tudor houses was in the bay windows, parapets, and porticoes, whereof the two latter were intensely carved with all the forms that the most fantastic and grotesque imagination could supply. The exteriors of these porticoes were covered with carved entablatures, figures, and armorial bearings and devices. The galleries were lofty, wide, and generally more than a hundred feet in length; and the staircases were spacious and magnificent, often occupying a considerable portion of the mansion. Elizabeth herself does not appear to have set, during the passion of the period for architecture, any example to her subjects. She might have thought her father had done sufficient in building palaces; but, however, be that as it may, she encouraged the nobles of her court in great expenditure on their residences. With the exception of tbe royal gallery at Windsor, she herself did actually nothing; whilst on Kenilworth alone, Lord Leicester is supposed to have expended no less a sum than 60,000*l.*, an almost royal sum of money.

439. Before proceeding further, it becomes our duty here to notice a peculiar construction which prevailed in the large manor houses of the provinces, and more especially in the counties of Salop, Chester, and Stafford, the memory of many whereof, though several are still to be seen, is chiefly preserved in engravings; — we allude to those of timber framework in places where the supply of stone or brick, or both, was scanty. The carved pendants, and the barge-boards of the roofs and gables, which had, however, made their appearance at a rather earlier period, were executed in oak or chesnut with much beauty of design, and often with a singularly pleasing effect. The timbered style reached its zenith in the reign of Elizabeth, and is thus illustrated in Harrison's description of England: — "Of the curiousnesse of these piles I speake not, sith our workmen are grown generallie to such an excellence of devise in the frames now made, that they farre passe the finest of the olde." And, again: "It is a worlde to see how divers men being bent to buildinge, and having a delectable view in spending of their goodes by that trade, doo dailie imagine new devises of their owne to guide their workmen withall, and those more curious and excellent than the former." (p. 336.) The fashion was no less prevalent in cities and towns than in the country; for in them we find that timber-framed houses abounded, and that they also were highly ornamented with carvings, and exhibited in their street fronts an exuberance of extremely grotesque figures performing the office of corbels. The fashion was imported from the Continent, which supplies numberless examples, especially in the cities of Rouen, Bruges, Ulm, Louvaine, Antwerp, Brussels, Nuremburg, and Strasburg, which very far surpass any that this country can boast. We have, however, sufficient remains of them in this country to prove that the wealthy burgess affected an ornamental display in the exterior of his dwelling, rivalling that of the aristocracy, and wanting neither elegance nor elaborate finishing, whilst it was productive of a high picturesque effect in the street architecture of the day. "This manner," says Dallaway, "was certainly much better suited to the painter's eye than to comfortable habitation; for the houses were lofty enough to admit of many stories and subdivisions, and being generally placed in narrow streets were full of low and gloomy apartments, overhanging each other, notwithstanding that they had fronts nearly composed of glass, with the projecting windows and the interstices filled for nearly the whole space." *Fig.* 201. is a representation of Morton Hall, an example of the style in question.

440. A better idea of the architecture of this age cannot be obtained than by a notice of the principal architects who have furnished materials for the foregoing observations; and for this purpose we shall use with freedom the notes to Walpole's anecdotes, by our late much valued friend Mr. Dallaway. A MS., belonging to the Earl of Warwick

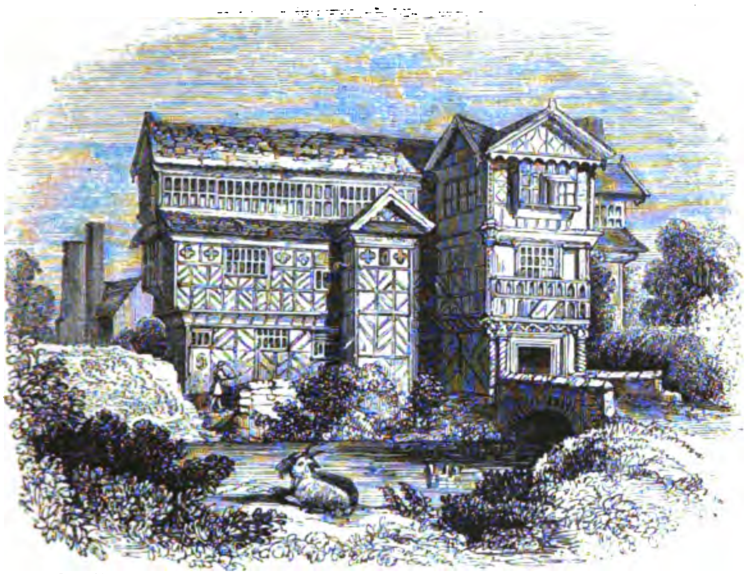


Fig. 201. TIMBER-FRAMED HOUSE, MORTON HALL.

in the time of Walpole, enabled him to bring to the knowledge of the world, and perpetuate the memory of, an artist of no mean powers, whose name, till that author's time, was almost buried in oblivion, though he was the architect of most of the principal and palatial edifices erected during the reigns of Elizabeth, and James, her successor. His name was John Thorpe; and at the sale of the library of the Hon. Charles Greville in 1810, the MS. in question came into the possession of the late Sir John Soane, Professor of Architecture to the Royal Academy. It is a folio, consisting of 280 pages, wherein the plans, often without a scale, are nevertheless accurately executed. Several of the subjects were merely designs for proposed mansions. The elevations are neatly drawn and shadowed. The general form of the plans is that of three sides of a quadrangle, the portico in the centre being an open arcade finished by a turreted cupola. When the quadrangles are perfect, they are, for convenience, surrounded by an open corridor. The windows, especially in the principal front, are large and lofty, and mostly alternated with bows or projecting divisions, and always so at the flanks. The ornaments are of the cinque cento school, as far as it was understood here, and are universally rude imitations of the works of Lescot and Vignola, — of the latter, of course, much debased. Great efforts were made by Thorpe to group the chimneys, which were embellished with Roman Doric columns, and other conceits. The contents of the volume are as follow : —

1. The ground plan of Old Somerset House.
2. Buckhurst House in Sussex, whereof are a ground plan and elevation. The front extends 230 ft. The quadrangle is 100 ft. by 80 ft., and the hall 80 ft. by 50 ft.
3. (Page 24.) The garden front of a nobleman's house, probably only a design.
4. " The way how to drawe any ground plot into the order of perspective," with diagrams and written descriptions.
5. A design for a large house with three sides of a quadrangle.
6. An elevation of a house for Sir Thomas Dorrell in Lincolnshire.
7. Godstone. An open corridor of the Doric order.
8. Copthall in Essex, built for Sir Thomas Heneage, to whom the manor was granted by Queen Elizabeth. The gallery, of extraordinary length, as compared with its height and width, was 168 ft. long, 22 ft. high, and the same wide; and the inner court of the mansion was 83 ft. square.
9. Wollaton Hall, Nottinghamshire, the inscription whereon runs thus: " *En has Francisci Willoughbæi Ædes, rara arte constructas Willoughbæis relictas. Inchoatæ*, 1580—1588. Mr. Dallaway observes, on this inscription, that the monument of Robert Smithson in Wollaton Church appears to invalidate Thorpe's claim to this design. It runs thus: " Mr. Robert Smithson, architector and surveyor unto the most worthy house of Wollaton, with divers others of great account, ob. 1614." He was probably Thorpe's pupil and successor.

10. A design of a quadrangle intersected by a corridor.
11. Sir John Bagnall's house, with a gallery above 60 ft. in length.
12. Burleigh House, built for Cecil the Lord Treasurer: but it exhibits only the plans of the ground and first floors, with designs and sketches for the scroll parapet.
13. Some details for Sir George St. Poole.
14. Thornton College, with a gallery 100 ft. long, for Sir Vincent Skinner.
15. A ground plan for Sir Thomas Holte.
16. A design.
17. The house called Holland House, at Kensington, for Sir Walter Coapes. This was finished by Thorpe in 1607, and afterwards received alterations and additions from the hands of Inigo Jones and Stone.
18. Giddea Hall, Essex; altered for Sir Anthony Coke, who there entertained Queen Elizabeth.
19. For Sir George Coppen.
20. Burghley on the Hill. Garden front.
21. " A front or garden side for a nobleman, three breadths of ordinary tenements;" supposed to have been for Sir Robert Greville's (Lord Brooke) house, near Gray's Inn.
22. " A London house for Mr. Darby."
23. Wimbledon. " A house stands upon the edge of a hill," built for Sir Thomas Cecil in 1588. Fuller says it was nearly equal to Nonsuch. It was rebuilt by Sarah Duchess of Marlborough, and was consumed by fire.
24. " Queene Mother's House," altered by I. Thorpe.
25. " Monsieur Jammet in Paris, his house, 1620. All his offices are under grounde."
26. Jannin's house, five leagues from Paris, an. 1600.
27. An elevation for Sir William Haslerigg.

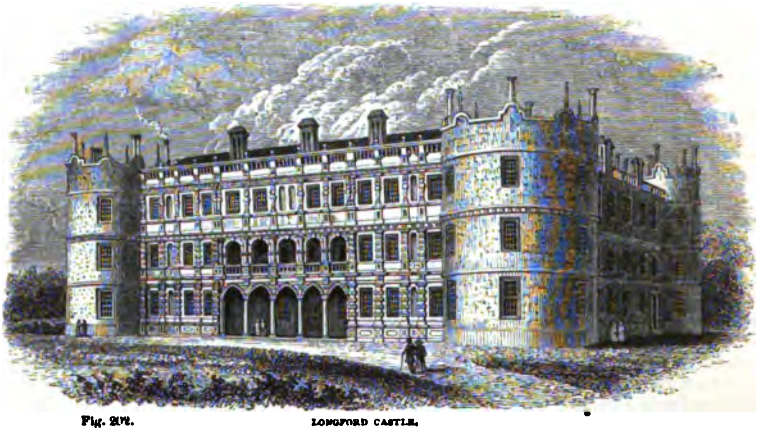


Fig. 202. LONGFORD CASTLE.

28. Longford Castle, Wiltshire (*fig.* 202.). A most singular production. A diagram of the Trinity drawn in the centre of a plan of the triangular court. It was erected for Sir Thomas Georges and his lady, the Marchioness Dowager of Northampton, in 1591, and is now the seat of the Earl of Radnor.
29. A plan for Sir Percival Hart, Lullingstone, Kent.
30. A house for Mr. Panton.
31. Holdenby, built for Sir Christopher Hatton in 1580, and now in ruins. Two large quadrangles in the plan, and an elevation of the front.
32 and 33. Plans for Mr. William Fitzwilliam and Sir Henry Neville.
34. Audley End; plan of the two courts. Thorpe's part completed about 1616. Much reduced in size since, and now the property of Lord Braybroke.
35. A design.
36. Mr. Taylor's house at Potter's Bar.
37. Sir Walter Covert's in Sussex, whereof the ruined walls are still standing.
38. Hatfield Lodge, a plan.
39 and 40. Drawings relating to Ampthill.
41. " Kirby, whereof I laid the first stone." This was a house for John Kirby, citizen of London, whose death is mentioned by Fleetwood, Recorder of London, in a letter to the Lord Treasurer Burleigh. He had built a fair house on Bethnal

Green, whose loftiness and similitude to a castle, caused some ridicule of him by the rhymesters of the day

441. Walpole, upon *Thorpe's Compositions*, observes, that the taste of this master's mansions was that " bastard style which intervened between Gothic and Grecian architecture, or which, perhaps, was the style that had been invented for the houses of the nobility when they first ventured, on the settlement of the kingdom after the termination of the quarrel between the Roses, to abandon their fortified dungeons, and consult convenience and magnificence." The same author continues, " Thorpe's ornaments on the balustrades, porches, and outsides of windows are barbarous and ungraceful, and some of his vast windows advance outwards in a sharp angle; but there is judgment in his disposition of apartments and offices, and he allots more ample space for halls, staircases, and chambers of state. He appears, also, to have resided at Paris, and even seems to have been employed there." Among the designs he made is that of a whimsical edifice, designed for himself, forming on the plan the initial letters of his name IT, which are joined by a corridor, the I being the situation of the offices, and the T being skilfully distributed into large and small apartments. The epigraph to the design is as follows: —

> " Thes 2 Letters I and T "
> " Joyned together as you see "
> " Is meant for a dwelling house for mee "
> " JOHN THORPE "

Walpole truly observes of this volume, that " it is a very valuable record of the magnificence of our ancestors, and preserves memorials of many sumptuous buildings of which no other monument remains." We ought, perhaps, to have suffered our account of Thorpe to have been preceded by those of others, but the conspicuous rank he holds in the list of English architects of this period induced us to place him before another, for a little time his predecessor in the works of the country. We allude to the name of Robert Adams, who translated Ubaldini's account of the defeat of the Spanish Armada from the Italian into Latin; a feat which we fear but few architects of the present day would easily accomplish, such is the fall of education for artists, notwithstanding all the boasts of march of intellect. This translation appeared in 4to., 1589. He was surveyor of the queen's buildings, and appears to have been a man of considerable ability. His place of sepulture was in an aisle on the north side of the old church at Greenwich, with this inscription, " Egregio Viro, Roberto Adams, operum regiorum supervisori architecturæ, peritissimo, ob. 1595. Simon Basil, operationum regiarum contrarotulator, hoc posuit monumentum 1601."

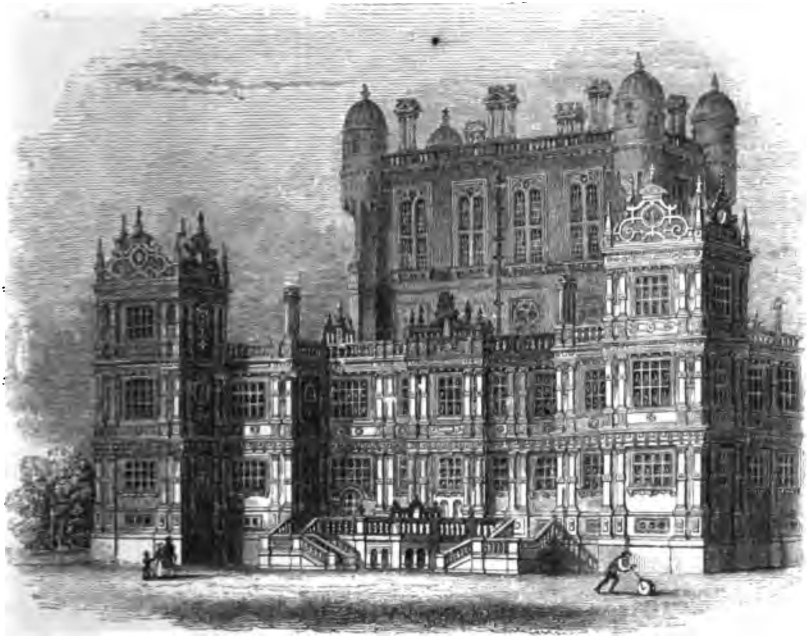


Fig. 203. WOLLATON HALL.

442. Bernard Adams and Lawrence Bradshaw were also eminent among the architects of the period under our consideration; but we must notice more particularly Gerard Christmas, who was associated with Bernard Jansen in the erection of Northampton, afterwards Suffolk, and now Northumberland House, not strictly belonging in time, though in style, to the reign of Elizabeth. Both of these architects had acquired considerable fame, and were, deservedly, much employed. In Northumberland House the cyphers of Christmas, C. Æ. (Christmas ædificavit), were used in the street front. The letters H. N. were originally in the balustrade here, standing for Howard Earl of Northampton, and were frequently repeated, a practice then much in vogue, for there are many examples of inscriptions of letters enclosed within the balustrade, as if within lines, and pierced so that the sky seen through them renders them distinct from almost every point of view. Bernard Jansen was probably the architect first employed at the splendid mansion of Audley Inn in Essex, for Thomas Howard Earl of Suffolk; and, besides the association with Christmas above mentioned, was joined with Moses Glover in completing Northumberland House, and was probably the architect who finished Sion House in Middlesex, for Henry Earl of Northumberland, who had at the time expended 9000*l*. in the work.

443. Robert and Huntingdon Smithson, father and son, were engaged on Wollaton Hall (*fig.* 203. at the foot of the preceding page), in Nottinghamshire, as also at Bolsover in Derbyshire. The former died in 1614, at the age of seventy-nine, and the latter in 1648, but it is pretty certain that Thorpe was consulted in this splendid work, for among his designs, as the reader will recollect, are some for Wollaton.

444. Thomas Holte, a native of York, was the architect of the public schools at Oxford (*fig.* 204.), of which the hint might have been taken from the Campanile of Santa Chiara at Naples, and of the quadrangles of Merton and Wadham colleges. He was the first in this country who introduced the classical orders in series above each other. He evidently borrowed the practice from Philibert Delorme, who had done the same thing at the Chateau d'Anet, near Paris, one of the victim edifices of the Revolution. We apprehend any argument to prove the absurdity of such conceits is unnecessary.

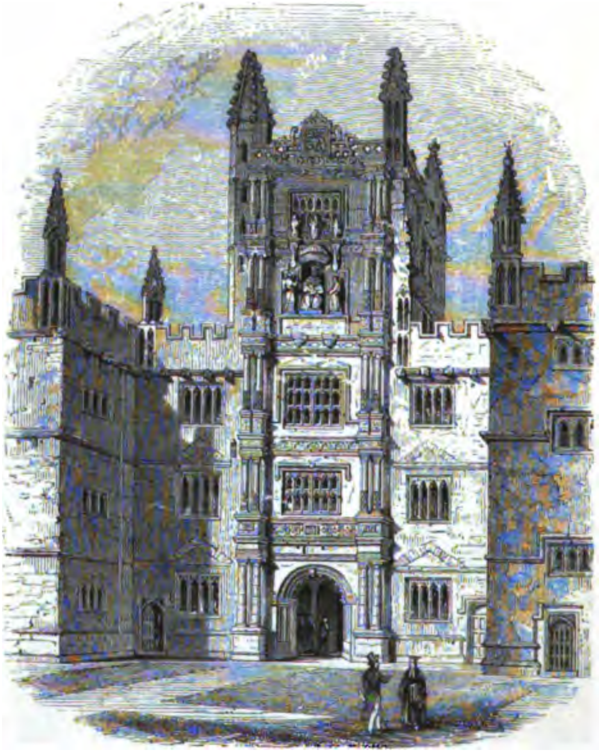


Fig. 204. PUBLIC SCHOOLS AT OXFORD.

445. Many of the grandest works of what is termed the Elizabethan, or, in truth, the

last Tudor style, were not completed before the middle of the reign of James I.; so that it may be said to have been practised until the days of Inigo Jones, in whose early works it may be traced. "This fashion," says Dallaway, "of building enormous houses was extended to that period, and even to the civil war. Audley Inn, Hatfield, Charlton, Wilts, and particularly Wollaton, are those in which the best architecture of that age may be seen. Others of the nobility, deserting their baronial residences, indulged themselves in a rivalship in point of extent and grandeur of their country-houses, which was, of course, followed by opulent merchants, the founders of new families. Sir Baptist Hickes, the king's mercer (afterwards ennobled), built Campden House, Gloucestershire, which was scarcely inferior to Hatfield, afterwards burnt down. There is scarcely a county in England which cannot boast of having once contained similar edifices; a very few are still inhabited; others may be traced by their ruins, or remembered by the oldest villagers, who can confirm the tradition; and the sites, at least, of others are pointed out by descriptions as having existed within the memory of man."

446. The following is a list of some of the principal palatial houses finished before 1600. Others of the reign of Elizabeth's successors will hereafter be noticed. Of so many of them are the names of the architects undetermined, though many are assigned to those we have already mentioned, that we shall not attempt to assign a column to the artists in question, for fear of misleading our readers.

Name.	Date.	County.	Founder.	Present State.
Catledge - -	1560	Cambridge	Lord North - -	Taken down.
Basinghouse -	-	Hants -	Marquis of Winton -	In ruins.
Kelston - -	-	Somerset -	Sir J. Harrington -	Rebuilt.
Gorhambury -	1565	Herts -	Sir N. Bacon - -	In ruins.
Buckhurst -	-	Sussex -	Lord Buckhurst - -	Destroyed.
Knowle - -	1570	Kent - -	Lord Buckhurst -	Perfect.
Penshurst -	-	Kent -	Sir H. Sydney - -	Perfect.
Kenilworth -	1575	Warwick -	Earl of Leicester -	In ruins.
Hunsdon - -	-	Warwick -	Lord Hunsdon - -	Rebuilt.
Wanstead -	1576	Essex -	Earl of Leicester -	Destroyed.
Burleigh -	1577	Lincoln -	Lord Burleigh - -	Perfect.
Osterley - -	-	Middlesex -	Sir Thomas Gresham -	Rebuilt.
Longleat -	1579	Wilts -	Sir J. Thynne - -	Perfect.
Stoke Pogis -	1580	Bucks -	Earl of Huntingdon -	Rebuilt.
Toddington -	-	Beds -	Lord Cheyney - -	Destroyed.
Theobalds -	-	Herts -	Lord Burleigh - -	Destroyed.
Wimbledon -	1588	Surrey -	Sir T. Cecil - -	Rebuilt.
Westwood -	1590	Worcester -	Sir J. Packington -	Perfect.
Hardwick Hall -	1597	Derby -	Countess of Shrewsbury -	In ruins.

447. Relative to Osterley, in the above table, a curious anecdote has been preserved by Fuller, in his *Worthies of Middlesex*. Queen Elizabeth, when visiting its magnificent merchant, the owner, observed to him that the court ought to have been divided by a wall. He immediately collected so many artificers, that before the queen had risen the next morning, says the historian, a wall had been actually erected.

448. Many of these houses possessed terraces of imposing grandeur, which were connected by broad or double flights of steps, with balustrades, whereof, if we may judge from Winstanley's print of Wimbledon, the seat of Sir Edward Cecil, it was a very fine example. The following extracts from the parliamentary survey of it in 1649 will convey some notion of its extent. "The scite of this manor-house being placed on the side slipp of a rising grownde, renders it to stand of that height, that betwixt the basis of the brick wall of the lower court, and the hall door of the sayd manor-house, there are five several ascents, consisting of three score and ten stepps, which are distinguished in a very graceful manner. The platforms were composed of Flanders brick, and the stepps of freestone, very well wrought. On the ground floor was a room called the stone gallery, 108 foot long, pillared and arched with gray marble." The ceiling of the hall "was of fret or parge work, in the middle whereof was fixed one well-wrought landskip, and round the same, in convenient distances, seven other pictures in frames, as ornaments to the whole roome; the floor was of black and white marble."

449. As we have above observed, the Elizabethan style is a mixture of Gothic and Italian. It is characterised by orders very inaccurately and rudely profiled; by arcades whose openings are often extravagantly wide, their height not unfrequently running up into the entablature. The columns on the piers are almost universally on pedestals, and are often banded in courses of circular or square blocks at intervals of their height; when square, they are constantly decorated with prismatic raisings, in imitation of precious stones, a species of

ornament which is of very frequent recurrence. Nothing like unbroken entablatures appear; all is frittered away into small parts, especially in scrolls for the reception of inscriptions, which, at their extremities, are voluted and curled up, like so many pieces of scorched leather. All these eccentricities are so concentrated in their sepulchral monuments, that no better insight into the leading principles of the style can be afforded than an example from Westminster Abbey, here given in the monument of Queen Elizabeth herself (*fig.* 205.). In this it will be seen that the taste is cumbrous and confused; and to add to the anomalies, the figures were coloured, and the different sorts of marbles and alabasters of numberless hues. The general composition consists in a large altar tomb under an open arcade, with a rich and complicated entablature. The columns are usually of black or white marble, of the Doric or Corinthian order. Small pyramidal figures, whose sides were richly veneered with variously coloured pieces, disposed in ornamented squares or circles supporting globes, are of continual occurrence. Armorial bearings in their various colours were introduced to excess. When the monument is placed against a wall, which is more usually the case, the plan was accommodated to it, and the alcove with its columns universally retained. Among the best examples are those of Ratcliffe Earl of Surrey at Boreham, and of his countess in Westminster Abbey; of Dudley Earl of Leicester at Warwick, and of Carey Lord Hunsdon in Westminster Abbey.

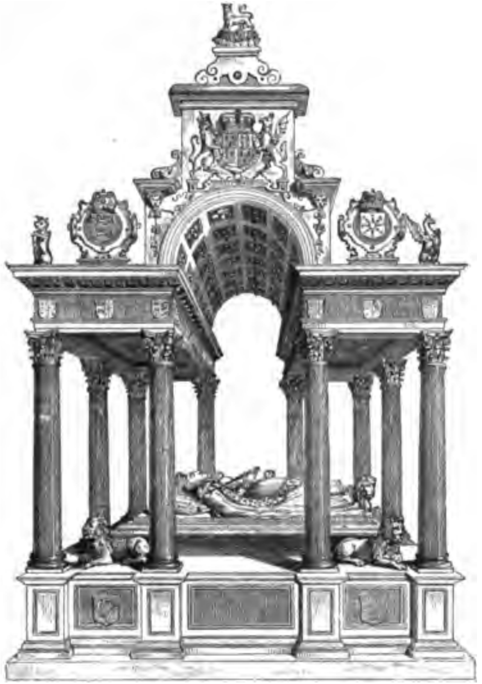


Fig. 205. QUEEN ELIZABETH'S MONUMENT.

450. It seems droll in this age, when throughout Europe the principles of good taste in architecture are so well understood, that fashion, induced by the cupidity and ignorance of upholsterers and decorators,—the curses of the art,—should again sanction an adoption of the barbarous forms and unmeaning puerilities which it might be supposed Jones and Wren had, by their example, consigned to a merited oblivion. We fear our warning voice will do little to suppress the rage till its cycle is completed. We have, in the prolongation of the subject, sacrificed our own feelings to the rage in the present day for designs of this class, and have assigned to it a far longer description than it deserves. The wretched cockney imitations of it perpetrated for retired shopkeepers in the insignificant villas of the suburbs of the metropolis, and occasionally for the amusement of country gentlemen a little more distant, as well as the use of what is called Gothic, appear to us in no other light than mockeries of a style which is repudiated by the manners of the nineteenth century. The style called Elizabethan we consider quite as unworthy of imitation as would be the adoption in the present day of the model of the ships of war, with their unwieldly and top-heavy poops, which encountered the Armada, in preference to the beautiful and compact form of a well-moulded modern frigate.

Sect. VII.

JAMES I. TO ANNE.

451. The first of the reigns that heads this section has, in some measure, been anticipated in our notice of Elizabethan architecture, which it was impossible to keep altogether distinct

from the following reign. The angular and circular bay windows now disappeared entirely, and were supplanted by large square ones, of very large dimensions in their height, unequally divided by transoms, and placed in lengthened rows, so as to form leading features in the several stories of the building. Battlements were now entirely omitted, and the general effect of the pile became one of massive solidity, broken by a square turret loftier than those at the angles. The houses built in the reign of James I. are deficient in the picturesque beauty found in those of his predecessors. Many of them were finished by the architects named in the last section, and they were on a larger scale than even those of the age of Elizabeth. Audley Inn in 1616, Hatfield in 1611, and Charlton House in Wiltshire for Sir Henry Knevett, were, perhaps, the best specimens. The house at Campden, Gloucestershire, built by Sir Baptist Hickes, and which was burned down during the civil wars, consisted of four fronts, the principal one being towards the garden, upon the ground terrace; at each angle was a lateral projection of some feet, with spacious bay windows; in the centre a portico, with a series of the columns of the five orders (as in the schools at Oxford), and an open corridor. The parapet was finished with pediments of a capricious taste, and the chimneys were twisted pillars with Corinthian capitals. A very capacious dome issued from the roof, which was regularly illuminated for the direction of travellers during the night. This immense building was enriched with friezes and entablatures, most profusely sculptured; it is reported to have been erected at the expense of 29,000*l*., and to have occupied, with its offices, a site of eight acres."

452. The use of the orders became more general. In Glamorganshire, at Beaupré Castle (1600), which has a front and porch of the Doric order, we find a composition including that just named, the Ionic and the Corinthian, wherein the capitals and columns are accurately designed and executed. The following table exhibits some of the principal houses of the period: —

House.	Date.	County.	Founder.	Present State.	Architect.
Holland House	1607	Middlesex	Sir Walter Cope	Perfect	John Thorpe
Bramshill	-	Hants	Edward Lord Zouche	do.	Uncertain.
Castle Ashby	-	Northampton	Herbert Lord Compton	do.	do.
Summer Hill	-	Kent	Earl of Clanricarde	do.	do.
Charlton	-	Wilts.	Sir Henry Knevet	Restored	do.
Hatfield	1611	Herts.	Robert Earl of Salisbury	Perfect	do.
Longford Castle	1612	Wilts.	Sir T. Gorges	do.	John Thorpe.
Temple Newsham	-	Yorkshire	Sir Arthur Ingram	do.	Uncertain.
Charlton	-	Kent	Sir Adam Newton	do.	do.
Bolsover	1613	Derby	Sir Charles Cavendish	Dilapidated	Huntingdon and Smithson.
Audley Inn	1616	Essex	T. Earl of Suffolk	Perfect	B. Jansen.
Wollaton	-	Notts.	Sir Francis Willoughby	do.	J. Thorpe and Smithson.

453. Under James, the pride and magnificence of the aristocracy was as equally displayed in the sumptuous monuments erected to the memory of the departed as in their stately palaces; and we can scarcely point to a county in England whose parish churches do not attest the fact by the gorgeous tombs that exist in villages where the mansions of those thus commemorated have not long since passed from the memory of man. A year's rental of an estate, and that frequently under testamentary direction, was often squandered in the sepulchral monument of the deceased lord of a manor.

454. In the reign of James I. properly commences the career of Inigo Jones, to which we hasten with delight, as indicating the dawn of true architecture (for the Gothic had irretrievably passed away) in England. It resembles the arrival of a traveller at an oasis in the desert, after a parching and toilsome journey. "Jones, if a table of fame," says Walpole, "like that in the Tatler, were to be formed for men of real and indisputable genius in every country, would save England from the disgrace of not having her representative among the arts. She adopted Holbein and Vandyck, she borrowed Rubens, she produced Inigo Jones. Vitruvius drew up his grammar, Palladio showed him the practice, Rome displayed a theatre worthy his emulation, and King Charles was ready to encourage, employ, and reward his talents. This is the history of Inigo Jones as a genius." Generally speaking, we are not admirers of Walpole, who often sacrificed truth to fancy, and the character of an artist to a prettily-turned period; hence we are disinclined to concur in his criticisms without many qualifications; but in this case he has so well expressed our own

feelings, that we regret we cannot add force to the observations in which we so fully concur.

455. Inigo Jones was the son of a clothworker, and was born about 1572. From the most probable accounts he appears to have been apprenticed to a joiner, in which state he was, from some accounts, discovered by the Earl of Arundel, from others by William Earl of Pembroke, and by one or other of these noblemen sent to Italy, rather, however, according to Walpole, to study the art of painting, than that of architecture, for the former of which, the author named says, Nature appears not to have fitted him, inasmuch as "he dropped the pencil, and conceived Whitehall." But our own belief is, that though he might have afterwards been patronised by both the noblemen above mentioned, he owed this part of his education to neither of them; for, considering that at his first visit to Italy, before 1605, Lord Pembroke was but just of age, and that Lord Arundel was somewhat younger, there is no great probability that either of them thus assisted him in his studies on the Continent.

456. Of his employment as an architect nothing can be traced previous to the visit of James I. to the University of Oxford, in 1605, at which time he was thirty-three years old; and then, according to Leland (*Collectanea*, App. vol. vi. p. 647.), "They" (the University) "hired one Mr. Jones, a great traveller, who undertook to further them with rare devices, but performed little to what was expected. He had for his pains, I have constantly heard, 50*l.*;" from which it is certain that his earliest visit to Italy was before 1605. At Venice he became acquainted with the works of Palladio; and there, as Walpole observes, "learned how beautifully taste may be exerted on a less theatre than the capital of an empire." In this city his reputation was so great, that Christian IV. appointed him his architect, though of the buildings erected by him in Denmark we know nothing. In this country's capital, however, he was found by James, and by his Queen (Anne) was removed from Copenhagen to Scotland, in the quality of her architect. By Prince Henry he was employed in the same capacity, and about this time had the grant in reversion of surveyor general of the works. On the untimely and lamented death of that prince, he once more visited Italy, where he perfected his taste and ripened his judgment. It appears more than probable that it was previous to his second journey that he designed those of his buildings that partake of a bastard style. These buildings, however, are such as could, under the circumstances, have been designed only by a great master in a state of transition from one style to another; such, for instance, are the north and south sides of the quadrangle at St. John's College, Oxford, in which he seems to have copied all the faults of the worst examples of his great master Palladio; still the composition is so picturesque, that, though reluctantly, we cannot avoid admiring it. In the garden front of the same college (*fig.* 206.), notwithstanding its impurity, there is a breadth and grandeur which subdue criticism, and raise our admiration; and we by no means subscribe to Horace Walpole's dictum, that "Inigo's designs of that period have a littleness of parts and a weight of ornament." Previous to his second return to England, the surveyor's place had fallen in, and finding the office in debt, he prevailed, as Walpole observes, with an air of

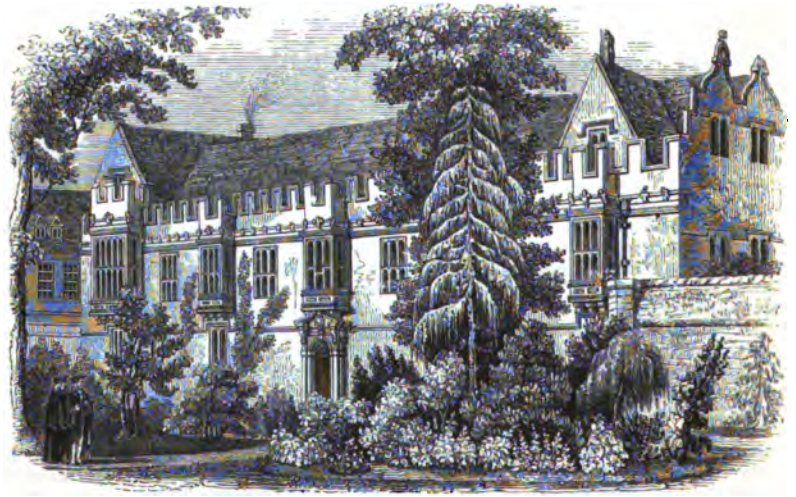


Fig. 206. GARDEN FRONT OF ST. JOHN'S.

Roman disinterestedness, and showing that architecture was not the only thing he had learned in Rome, on the comptroller and paymaster of the office, to give up, as he did, all the profits of the office till the arrears were cleared.

457. By the *Fœdera*, vol. xviii. p. 99., we find that there was issued to him, in conjunction with the Earl of Arundel and others, a commission to prevent the building on new foundations within two miles of London and the palace of Westminster; and in 1620 he was, if possible, more uselessly employed by James I. in guessing, for it was no more, who were the builders of Stonehenge. For this last, the necessary preliminary information had not even dawned, although Walpole, in his usual off-hand manner, loses not, in alluding to it, the opportunity of displaying his own dreadful ignorance on the subject. (See Chap. II. Sect. II., where this monument has been examined.) In the year last named, Jones was one of the commissioners for the repair of old St. Paul's, though the repairs were not commenced till 1633, in which year Laud, then Bishop of London, laid the first stone, and Inigo Jones the fourth. Our architect was now too much disinclined to Gothic to bend his genius to

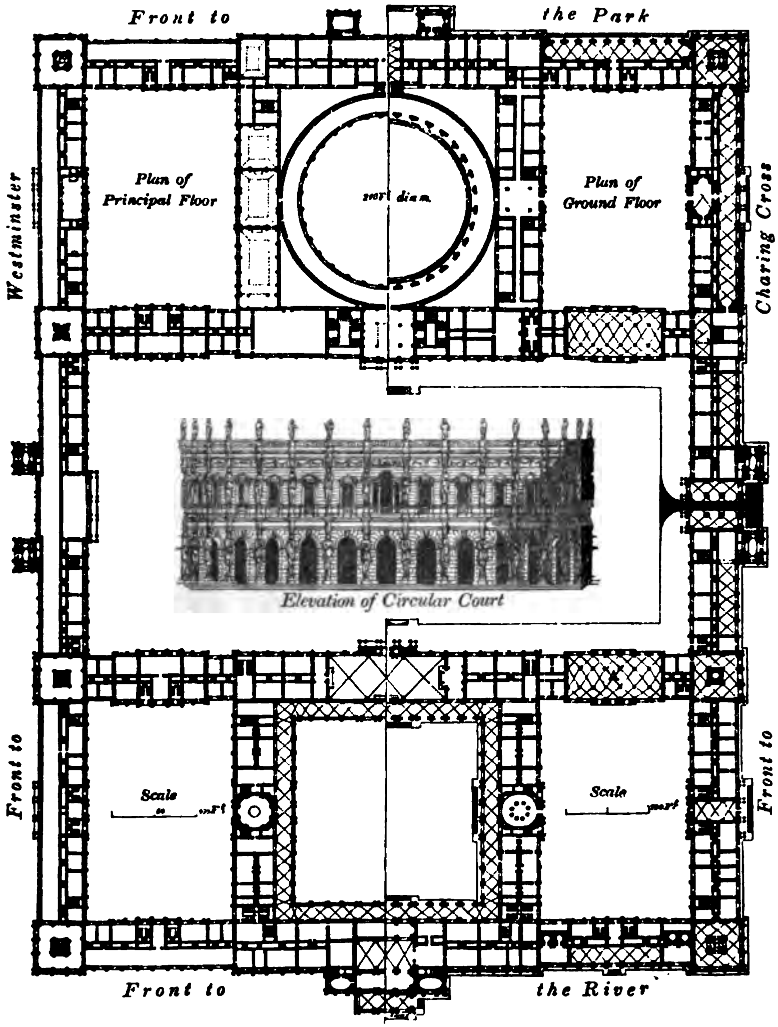


Fig. 207. PLAN OF WHITEHALL.

anything in the shape of a restoration; and though the Roman portico which he placed before the church was magnificent, the application of Roman to Gothic architecture of course ruined the cathedral. The reader will find a representation of this portico in Dugdale's *St. Paul's*. Abstractedly considered, it was a fine composition; and its dimensions, of a length of 200 ft., a depth of 50 ft., and a height of 40 ft., were calculated to give it an imposing effect.

458. The Banqueting House at Whitehall, which we have pride in quoting as one of the most magnificent works in Europe, has generally been supposed to have been erected in the reign of Charles I.; but there is sufficient reason for assigning the period of its execution to the preceding reign. It was begun in 1619, and finished in two years. The designs for the palace of Whitehall, whereof *fig.* 207. at the foot of the preceding page, exhibits a block plan, on which the banqueting-house (at A), it will be seen, forms a very inconsiderable portion, would, had they been executed, have formed, beyond all comparison, the finest in the world. In magnitude it would have exceeded even the palace of Diocletian. The form, as will be observed, was an oblong square, and consisted of seven courts, whereof six were quadrangular. The central one was larger than the other two chief divisions; and these were again subdivided into three courts, the centre one of which, on the north side, had two galleries with arcades, and that on the south a circular Persian court, as it was called, whose diameter was 210 ft. Surrounded on the ground floor by an open arcade, the piers between the arches were decorated with figures of Persians, with what propriety it is useless to discuss; and the upper story was ornamented between each window with caryatides, bearing Corinthian capitals on their heads, surmounted by an entablature of that order, and the whole was finished by a balustrade. Towards Westminster, the front extended 1152 ft.; and that towards the park, in which the length of the banqueting-house is included, would have been 720 ft. With the exception of Westminster Hall, the banqueting-house (now used as a chapel) is the largest room in England, its length being 115 ft., breadth 60 ft., and height 55 ft.

459. In 1623, Jones was employed on Somerset House, to the garden front whereof he executed (*fig.* 208.) a façade of singular beauty, lost to the world by its demolition on the rebuilding of the edifice for its present purposes. On the ascent of Charles I. to the throne, our architect seems to have been very much employed. As surveyor of the public buildings, his stipend was 8*s.* 4*d.* a day, besides an allowance of 46*l.* per annum for house-rent, a clerk, and incidental expenses.

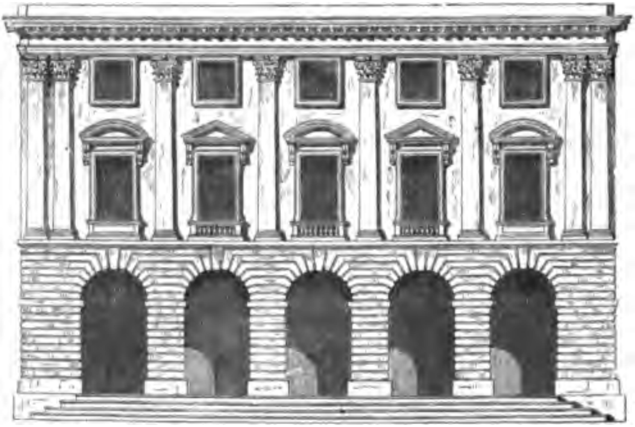


Fig. 208. WATER FRONT OF OLD SOMERSET HOUSE.

460. In the passion for masques which prevailed during the reign of Charles I., Jones was a principal contributor to their splendour. They had been introduced into this country by Anne of Denmark; and Walpole gives a list of thirteen to which he furnished the scenes and machinery.

461. Those that have seen Wilton can appreciate Inigo's merit for having introduced into England, in the seats of our aristocracy, a style vying with that of the villas of Italy. Some disagreement appears to have arisen between him and Philip Earl of Pembroke, which here it would be irrelevant to dwell on; we will merely mention that in the Harleian library existed an edition of Jones's *Stonehenge*, which had formerly belonged to the nobleman in question; and that its margins are filled by the former

possessor with notes, not on the substance of the work itself, but on its author, and anything else that could be injurious. He calls him "Iniquity Jones," and says he had 16,000*l.* a year for keeping the king's houses in repair. The censures were undeserved; and the accusations, unwarranted by facts, are extremely discreditable to the memory of Earl Philip.

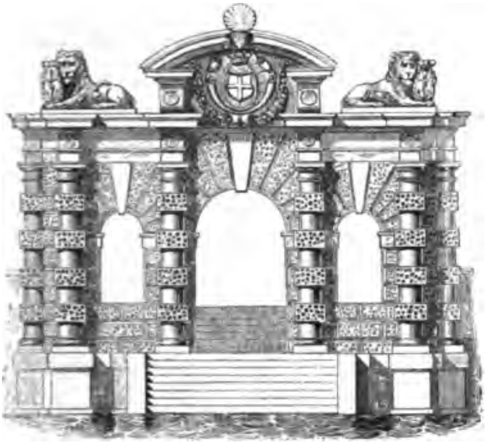


Fig. 209. YORK STAIRS.

462. The works of Jones were exceedingly numerous; many, however, are assigned to him which were the productions of his scholars. Such buildings as the Queen's house at Greenwich (much altered, and, indeed, spoiled, of late years, for the purpose of turning it into a public naval school); Coleshill, in Berkshire, built in 1650; Shaftesbury House, in Aldersgate Street; the square, as planned, of Covent Garden; and many other works, are strong proofs of the advancement of architecture during his career. York Stairs (*fig.* 209.), another of his examples, exhibits a pureness and propriety of character which appears to have been afterwards unappreciated by his successors, with Wren at their head, whose mention by the side of Jones is only justified by the scientific and constructive skill he possessed.

463. Jones was a follower of the Venetian school, which we have described in a previous section. His respect for Palladio is evinced by the circumstance of a copy of that great master's works being his companion on his travels through Italy. It is filled with his autograph notes, and is now deposited in the library of Worcester College, Oxford. Lord Burlington had a Vitruvius noted by him in a similar manner. It is curious to see the amateurs and pseudo-critics of the present day decry these two authors, whom Jones, a genius of the first order, thought his best instructors. The class in question are, however, no longer considered worthy of being listened to on matters of the art; and the public taste is, in this respect, turning once more into the proper channel. Palladian architecture, thus introduced by Jones, would have reached a splendour under Charles I. perhaps equal to that which Italy can boast, had not its progress been checked by public calamities, in which it was the lot of the artist to share the misfortunes of his royal master. In addition to being the favourite of the king, he was a Roman Catholic; and for this (as it was then curiously called) delinquency, he had to pay 545*l.* in the year 1646. Grief, misfortunes, and a consequent premature old age, terminated the life of this great man at Somerset House on the 21st of July, 1651.

464. The plans of houses introduced from Italy by this master were not, perhaps, altogether suited to the climate or habits of the English. One of his greatest faults was that of aiming at magnificence under circumstances in which it could not be attained. Thus, his rooms were often sacrificed to the show and effect resulting from a hall or a staircase, or both; sometimes, to gain the appearance of a vista of apartments, they were made too small for the scale of the house. His distribution of windows is purely Italian, and the piers between them consequently too large, so that the light is occasionally insufficient in quantity. The habits of Italy, which enabled Palladio to raise his principal floor, and to have the farm offices and those for the vintage in the same range of building as the mansion, impart an air of great magnificence to the Italian villa. Jones saw that this arrangement was not required for English convenience, and therefore avoided the Palladian practice; "but," says Mitford, "the architects who followed him were dazzled, or dazzled their employers. To tack the wings to the centre with a colonnade became a phrase to express the purpose of plan of the most elegant effect; and the effect, provided the combination be harmonious, will be elegant; but the arrangement is very adverse to general convenience, and especially in the moderate scale of most general use. Where great splendour is the object, convenience must yield to it. Magnificence must be paid for in convenience as well as money." Webb and Carter were the pupils of Jones. The former will furnish us presently with a few remarks. During the time of the Commonwealth, the history of architecture in this country is a complete blank. We know of no public work of consequence that was designed or executed in the interregnum. On the restoration of

the monarchy, however, the art began to revive; but it was much tinctured with the contemporary French style, which Lord Burlington, on its reappearance many years afterwards, had the merit of reforming, and of bringing back the public taste to the purity which Jones had introduced: but this we shall have to notice hereafter.

465. John Webb was the nephew as well as scholar of Inigo Jones, whose only daughter he married. He built a large seat for the Bromley family at Horseheath, in Cambridgeshire; and added a portico to the Vine, in Hampshire, for Challoner Chute, the Speaker to Richard Cromwell's parliament. Ambresbury, in Wiltshire (*fig.* 210.), was only executed by him from the designs of his master, as also the east side of the court of Greenwich Hospital. Captain William Winde, a native of Bergen-op-Zoom, and pupil to Sir Balthazar Gerbier, was, soon after the Restoration, in considerable employ as an architect. He built Cliefden House, Bucks, which was destroyed by fire in 1795; the Duke of Newcastle's, in Lincoln's Inn Fields; Combe Abbey, Warwickshire, for Lord Craven; and for the same peer he finished Hempsted Marshall, which had been begun by his master. But the chief and best work of Winde was Buckingham House, in St. James's Park, on whose site now stands a palace, larger, indeed, but unworthy to be its successor. It is known from prints, and not a few of our readers will probably recollect the building itself. It was erected for John Sheffield, Duke of Buckingham; and on its frieze was the inscription "SIC SITI LÆTANTUR LARES." The arrears in the payments for this house, according to an anecdote in Walpole, were so distressing, that when it was nearly finished, "Winde had enticed his Grace to mount upon the leads to enjoy the grand prospect. When there, he coolly locked the trap-door, and threw the key to the ground, addressing his astonished patron, 'I am a ruined man, and unless I have your word of honour that the debts shall be paid, I will instantly throw myself over.' 'And what is to become of me,' said the duke? 'You shall come along with me.' The promise was given, and the trap-door opened (upon a sign made) by a workman in the secret, and who was a party to the plot." We do not vouch for the truth of the tale.

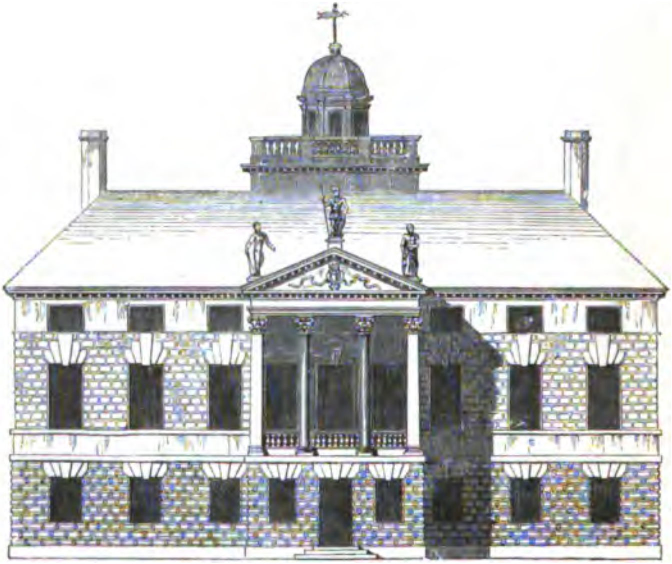


Fig. 210. AMBRESBURY.

466. An architect of the name of Marsh is said, by Vertue, to have designed the additional buildings at Bolsover, as also to have done some considerable works at Nottingham Castle; and Salmon, in his account of Essex, mentions a Doctor Morecroft, who died in 1677, as the architect of the manor-house of Fitzwalters. Of the works of the French taste about the middle of the period under discussion, a better notion cannot be obtained than from Montague House, now the British Museum (*fig.* 211.), the work of a Frenchman here whose example had followers; indeed, Wren himself, in some of his works, has caught the vices of the French school of the day, though he was a follower of the Venetian and Roman schools. The fire which destroyed London in 1666, a few years after the death of Jones, brought into notice the talents of Sir Christopher Wren, whose career was opened under

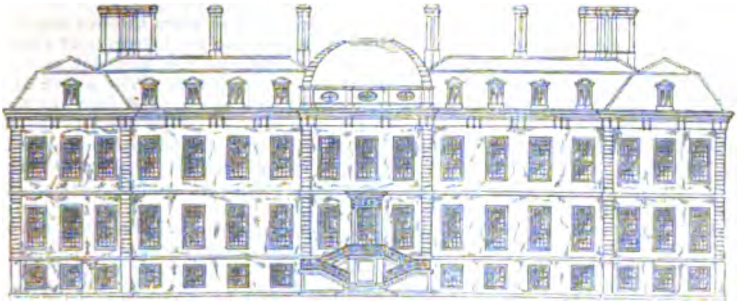


Fig. 211. BRITISH MUSEUM.

the reign of Charles II. “ The length of his life enriched the reigns of several princes and disgraced the last of them.” (At the advanced age of 86 he was removed by George I. from the office of Surveyor General.) “ A variety of knowledge proclaims the universality, a multiplicity of works the abundance, St. Paul's the greatness, of Sir Christopher's genius. The noblest temple, the largest palace, the most stupendous hospital, in such a kingdom as Britain, are all works of the same hand. He restored London and recorded its fall.” As the boast of England is the Cathedral Church of St. Paul, it will be necessary to dwell a little on a description of it.

467. The larger portion of this cathedral stands on part of the site of the old one, as shown by the annexed diagram (*fig.* 212.), which also exhibits their comparative sizes. It is

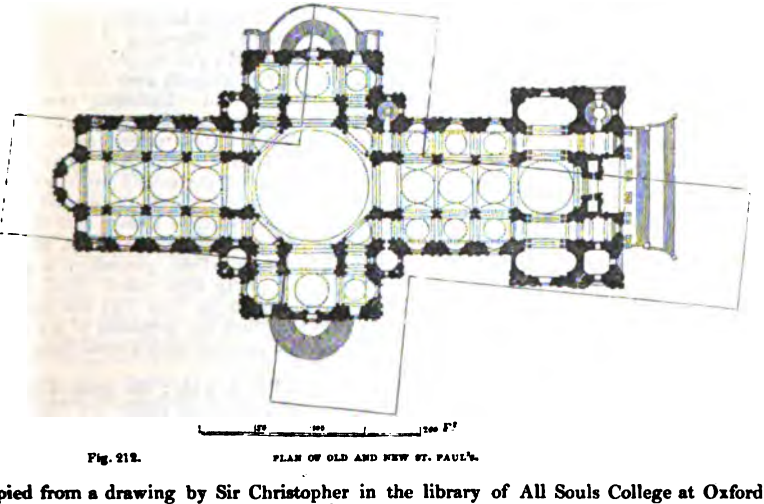


Fig. 212. PLAN OF OLD AND NEW ST. PAUL'S.

copied from a drawing by Sir Christopher in the library of All Souls College at Oxford. The instructions to the surveyor, according to the compiler of the Parentalia, were — “ to contrive a fabric of moderate bulk, but of good proportion; a convenient quire, with a vestibule and porticoes, and a dome conspicuous above the houses:” and in conformity with them, a design was made which, from various causes, does not appear to have given satisfaction; whereon the compiler observes, that “ he endeavoured to gratify the taste of the connoisseurs and criticks with something coloss and beautiful, with a design antique and well studied, conformable to the best style of the Greek and Roman architecture.” The model made from this design is still preserved in the cathedral. This however was, unfortunately, not approved, and, as our informant continues, “ the surveyor then turned his thoughts to a cathedral form, so altered as to reconcile as near as possible the Gothic to a better manner of architecture.” These last designs were approved by Charles, who issued his warrant under privy seal on the 1st of May, 1675, for the execution of the works.

468. Much trouble was experienced in removing the immense ruins of the old church, for the destruction whereof recourse was had to many expedients. On the north side, the foundations are placed upon a stratum of hard pot earth about 6 ft. in thickness, but not more

than 4 ft. thick on the south side; and upon this stratum, from the experience of the old church having firmly rested, the architect wisely determined to place the new one. The work was commenced on the western side, driving eastward to the extremity of the site; at which, on the northern side, a pit was discovered whence the hard pot earth had been extracted, and the vacuity so made filled up with loose rubbish. The length of this hole in the direction of the foundation was not more than 6 or 7 ft., and from the fear of piles, if driven, becoming rotten, the surveyor determined to excavate through the sand, and to build up from the stratum solid for a depth of 40 ft. The pit sunk here was 18 ft. wide; in this he built up a pier, 10 ft. square, till it rose to within 15 ft. of the present surface. At this level he introduced an arch from the pier to the main foundation, and on this arch the north-eastern quoin of the choir is founded.

469. On the 21st of June, 1675, the first stone was laid; and, within ten years, the walls of the choir and its side aisles, and the north and south circular porticoes, were finished; the piers of the dome also were brought up to the same height. The son of the architect laid the last stone in 1710. This was the highest stone on the top of the lantern. Thus the whole edifice was finished in thirty-five years, under the remarkable circumstances of having only one architect, one master mason (Mr. Strong), and the see being occupied the whole time by one bishop, Doctor Henry Compton.

470. The plan of St. Paul's is a Latin cross, and bears a general resemblance to that of St. Peter's. A rectangular parallelogram, 480 ft. from east to west (measuring from the top of the steps of the western portico to the exterior of the eastern wall of the choir), is crossed by another parallelogram, whose extremities form the transepts, 250 ft. in length from north to south. At the eastern end of the first parallelogram is a hemicylindrical recess, containing the altar, and extending 20 ft. further eastward; so that the whole length is 500 ft., exclusive of the flight of steps. At the north and south ends of the transepts are porticoes, segmental on the plan, and projecting 20 ft. The centre of the intersection of the parallelograms is 280 ft. from the western front. The width of each parallelogram is 125 ft. At the western end of the edifice, on the north and south extremities, are towers whose western faces are in the same plane as the general front, but whose northern and southern faces respectively project about 27 ft. from the walls of the aisles of the nave; so that the whole width of the western front is about 180 ft. In the re-entering angles on each side, between the towers and the main building, are two chapels, each 50 ft. long and 20 ft. broad, open to the aisles of the nave at their western end. Externally two orders reign round the building. The lower one Corinthian, standing on a basement 10 ft. above the level of the ground, on the western side, where a flight of steps extending the whole breadth of the front, exclusive of the towers, leads to the level of the church. The height of this order, including the entablature, is 50 ft.; and that of the second order, which is composite, is one fifth less, or 40 ft.; making the total height 100 ft. from the ground to the top of the second entablature. The portico of the western front is formed with the two orders above mentioned, the lower story consisting of twelve coupled columns, and the upper one of eight; which last is surmounted by a pediment, whose tympanum is sculptured with the subject of the Conversion of St. Paul, in pretty high relief. Half of the western elevation, and the half transverse section, is given in *fig.* 213. At the northern and southern ends of the transepts the lower order is continued into porticoes of six fluted columns, standing, in plan, on the segment of a circle, and crowned with a semi-dome abutting against the ends of the transepts.

471. The porch of the western front is 50 ft. long and 20 ft. wide: the great doorway, being in the centre of it, leads to a vestibule 50 ft. square, at whose angles are four piers connected at top by semicircular arches, under which are placed detached coupled columns in front of the piers. The body of the church is divided into a nave and two side aisles, decorated with pilasters supporting semicircular arches; and on each side of the porch and vestibule is a passage which leads directly to the corresponding aisles. The choir is similarly disposed, with its central division and side aisles.

472. The entrances from the transepts lead into vestibules 25 ft. deep, and the whole breadth of the transept in length, each communicating with the centre by a central passage and its aisles formed between two massive piers and the walls at the intersections of the transepts with the choir and nave. The eight piers are joined by arches springing from one to the other so as to form an octagon at their springing points, and the angles between the arches, instead of rising vertically, *sail* over as they rise and form *pendentives*, which lead, at their top, into a circle on the plan. Above this a wall rises in the form of a truncated cone, which, at the height of 168 ft. from the pavement, terminates in a horizontal cornice, from which the interior dome springs. Its diameter is 100 ft., and it is 60 ft. in height, in the form of a paraboloid. Its thickness is 18 in., and it is constructed of brickwork. From the haunches of this dome, 200 ft. above the pavement of the church, another cone of brickwork commences, 85 ft. high, and 94 ft. diameter at the bottom. This cone is pierced with apertures, as well for the purpose of diminishing its weight as for distributing light between it and the outer dome. At the top it is gathered into a dome, in the

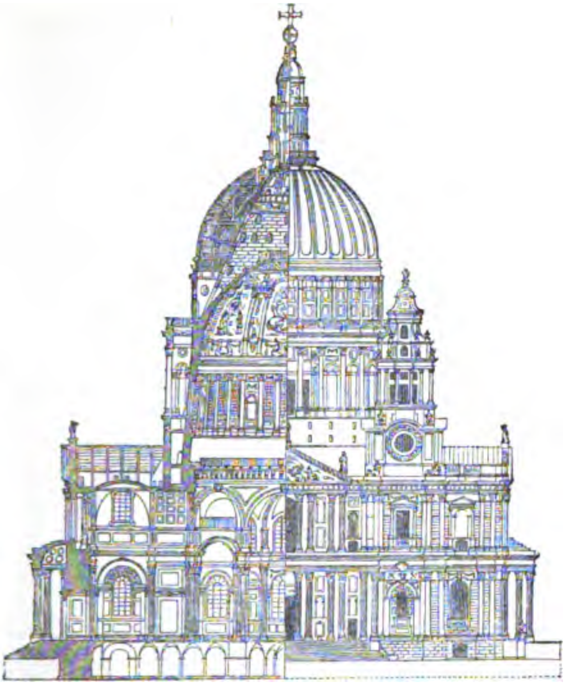


Fig. 213. HALF ELEVATION AND HALF SECTION OF ST. PAUL'S.

form of a hyperboloid, pierced near the vertex with an aperture 12 ft. in diameter. The top of this cone is 285 ft. from the pavement, and carries a lantern 55 ft. high, terminating in a dome, whereon a ball and cross is raised. The last-named cone is provided with corbels, sufficient in number to receive the hammer beams of the external dome, which is of oak, and its base 220 ft. from the pavement, its summit being level with the top of the cone. In form, it is nearly hemispherical, and generated by radii 57 ft. in length, whose centres are in a horizontal diameter, passing through its base. The cone and the interior dome are restrained in their lateral thrust on the supports by four tiers of strong iron chains, placed in grooves prepared for their reception, and run with lead. The lowest of these is inserted in the masonry round their common base, and the other three at different heights on the exterior of the cone. Externally the intervals of the columns and pilasters are occupied by windows and niches, with horizontal and semicircular heads, and crowned with pediments. In the lower order, excepting modillions under the corona, the entablature is quite plain, and there are also console modillions in the upper order. The edifice, in three directions, is terminated with pediment roofs; and at the extremities, on each of those faces, are acroteria, supporting statues 25 ft. above the roof of the edifice. Over the intersection of the nave and transepts for the external work, and for a height of 25 ft. above the roof of the church, a cylindrical wall rises, whose diameter is 146 ft. Between it and the lower conical wall is a space, but at intervals they are connected by cross walls. This cylinder is quite plain, but perforated by two courses of rectangular apertures. On it stands a peristyle of thirty columns of the Corinthian order, 40 ft. high, including bases and capitals, with a plain entablature crowned by a balustrade. In this peristyle, every fourth intercolumniation is filled up solid, with a niche, and connection is provided between it and the wall of the lower cone. Vertically over the base of that cone, above the peristyle, rises another cylindrical wall, appearing above the balustrade. It is ornamented with pilasters, between which are two tiers of rectangular windows. From this wall the external dome springs. As will be seen by reference to the section, the lantern which we have before noticed receives no support from it. It is merely ornamental, differing entirely in that respect from the dome of St. Peter's.

473. The towers in the western front are 220 ft. high, terminating in open lanterns, covered with domes formed by curves of contrary flexure, and not very purely composed, though perhaps in character with the general façade.

474. The interior of the nave and choir are each designed with three arches longitudinally springing from piers, strengthened, as well as decorated, on their inner faces, by an entablature, whose cornice reigns throughout the nave and church. Above this entablature, and breaking with it over each pilaster, is a tall attic from projections, on which spring semicircular arches which are formed into *arcs doubleaux*. Between the last pendentives are formed, terminated by horizontal cornices. Small cupolas, of less height than their semi-diameter, are formed above these cornices. In the upright plane space on the walls above the main arches of the nave, choir, and transepts, a *clerestory* is obtained over the Attic order, whose form is generated by the rising of the pendentives. The inner dome is plastered on the under side, and painted by Sir James Thornhill, with subjects relating to the history of St. Paul.

475. For external elegance, we know no church in Europe which exhibits a cupola comparable with that of St. Paul's, though in its connection with the church by an order higher than that below it there is a violation of the laws of the art. The cost of the church was 736,752*l.*, exclusive of the stone and iron enclosures round it, which cost 11,202*l.* more; in all 747,954*l.* About nine-tenths of that sum were raised by a tax on coals imported into London. As compared with St. Peter's, we subjoin a few of the principal dimensions of the two churches.

Direction of Measure.	St. Peter's in English Feet.	St. Paul's in English Feet.	Excess of the former in Feet.
Length within - -	669	500	169
Breadth at entrance - -	226	100	126
Principal façade - -	395	180	215
Breadth at the cross - -	442	223	219
Cupola, clear diameter -	139	108	31
Cupola, height of, with lantern	432	330	102
Church in height - -	146	110	36

476. If we suppose sections to be made through the transepts of the four principal churches of Europe, we have their relative sizes in the following ratio: —

St. Peter's, Rome - - - - - - -	1·0000
Santa Maria del Fiore, at Florence - - - -	·5358
St. Paul's, London - - - - - - -	·4166
St. Genevieve (Pantheon), Paris - - - - -	·3303

477. Notwithstanding its imposing effect as a whole, and the exhibition in its construction of a mechanical skill of the very highest order; notwithstanding, also, the abstract beauty of the greater number of its parts, it is our duty to observe that many egregious abuses are displayed in the fabric of St. Paul's, the first and greatest whereof is the great waste of interior effect as compared with the total section employed. If we suppose, as before, sections from north to south to be made through the transepts of the four principal churches, the following table will exhibit the proportion of their clear internal to their external areas: —

St. Peter's, Rome - - - - - -	8,325 : 10,000
Santa Maria del Fiore, Florence - - - -	8,855 : 10,000
St. Paul's, London - - - - -	6,865 : 10,000
St. Genevieve (Pantheon), Paris - - - -	6,746 : 10,000

Whence it is seen how highly in this respect the Duomo of Florence ranks above the others. The defect of St. Paul's in this respect is mainly induced by the false dome; and though we may admire the ingenuity that provided for carrying a stone lantern on the top of a truncated cone, deceitfully appearing, as it does, to stand on the dome from which it rises, we cannot help regretting that it afforded the opportunity of giving the building a cupola, liable to the early attack of time, and perhaps that, more to be dreaded, of fire.

478. In the skill required for raising a building on a minimum of foundation, Sir Christopher Wren appears to have surpassed, at least, those who preceded him. In similarly or nearly so formed buildings, some criterion of the comparative skill employed in their construction may be drawn from comparing the ratio between the area of the whole plan, and that of the sum of the areas of the horizontal sections of the whole of the piers, walls, and pillars, which serve to support the superincumbent mass. The similarity of the four churches already compared affords, therefore, a criterion of their respective merits in this respect. We hardly need say that one of the first qualifications of an architect is to produce the greatest effect by the smallest means. The subjoined table is placed before the reader as a comparison of the four churches in reference to the point in question.

Church.	Whole Area in English Feet.	Area of Points of Support.	Ratio.
St. Peter's at Rome - -	227,069	59,308	1 : 0·261
Sta. Maria del Fiore, Florence	84,802	17,030	1 : 0·201
St. Paul's, London - -	84,025	14,311	1 : 0·170
St. Genevieve (Pantheon), Paris	60,287	9,269	1 : 0·154

The merit, therefore, shown in the *construction* of the above edifices will be nearly as 15, 17, 20, 26, or inversely proportional to the numbers in the last column.

479. We must here mention one of the most unpardonable defects, or rather abuses, which this church exhibits, and which must be learnt from reference to *fig.* 214. Therein is given a transverse section of the nave and its side aisles. From this it will be seen that the enormous expense of the second or upper order all round the church was incurred for no other purpose than that of concealing the flying buttresses that are used to counteract the thrusts of the vaults of the nave, choir, and transepts, — an abuse that admits of no apology. It is an architectural fraud. We do not think it necessary to descend into minor defects and abuses, such as vaulting the church from an Attic order, the multiplicity of breaks, and want of repose; the general disappearance of tie and connection, the piercing, as practised, the piers of the cupola, and mitering the archivolts of its great arches, and the like, because we think all these are more than counterbalanced by the beauties of the edifice. We cannot, however, leave the subject without observing that not the least of its merits is its freedom from any material settlement tending to bring on premature dilapidation. Its chief failures are over the easternmost arch of the nave, and in the north transept, for the remedy whereof (the latter) the architect left written instructions. There are also some unimportant failures in the haunches of most of the flying buttresses, which are scarcely worth notice.

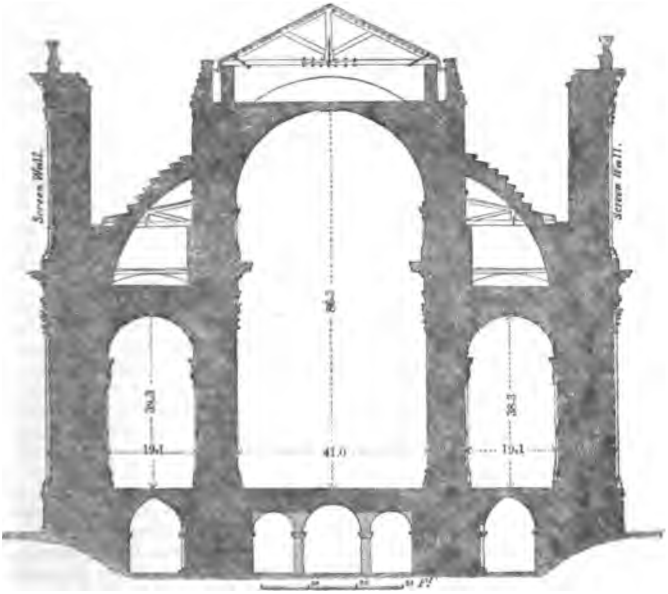


Fig. 214. ST. PAUL'S. SECTION WITH BUTTRESSES.

480. The wretchedly naked appearance of the interior of this cathedral is a disgrace neither to the architect nor to the country, but to the clergy, Terrick, bishop of London, and Potter, archbishop of Canterbury, who refused to sanction its decoration with pictures, gratuitously proffered by artists of the highest reputation; and this after the cupola itself had been decorated. The colour of the sculpture is of no use in heightening the effect of the interior.

481. The *Parentalia* contains a description of the manner in which the walls of the old

cathedral were destroyed, and those of the present one raised; which should be read by all those engaged in the practice of architecture.

482. Wren, having lived to see the completion of St. Paul's, died in 1723, at the age of 91, and was buried under the fabric, "with four words," says Walpole, "that comprehended his merit and his fame.

"SI QUÆRAS MONUMENTUM CIRCUMSPICE."

483. It will be impossible, consistently with our space, to describe the works of Sir Christopher Wren. One upon which his fame is as justly founded as upon St. Paul's itself, is St. Stephen's Church in Wallbrook, in which, on a plot of ground 80¼ ft. by 59½ ft., he has contrived a structure whose elegance is not surpassed by any one we know to have been raised under similar restrictions. The church in question is divided longitudinally into five aisles by four ranks of Corinthian columns standing on pedestals; the places of four columns near the centre being unoccupied; the surrounding central columns form the angles of an octagon, 45 ft. diameter, on which arches are turned, and above which, by means of pendentives, the circular base of a dome is formed, which is in the shape of a segment of a sphere, with a lantern thereon. The ceiling of the middle aisle from east to west is vaulted in groins. The rest of the ceiling is horizontal. The interior of St. James's, Westminster, is another beautiful example of the master, though recently underrated by an ignorant critic.

484. One of the peculiarities remarkable about Wren's period is the investment of the form of the Gothic spire with a clothing of Italian architecture, by which the modern steeple was produced. If any example could reconcile us to such a practice, it might be found in that of Bow Church, another of Wren's works, which rises to the height of 197 ft. from the ground, the sides of the square from which it rises being 32 ft. 6 in. There are, in the leading proportions of this tower and spire, some extraordinary examples in relative heights as compared with widths sesquilaterally, which would almost lead one to suppose that, in this respect, our architect was somewhat superstitious.

485. In St. Dunstan in the East, Wren attempted Gothic, and it is the least offensive of his productions in that style. It is an elegant composition, but wants the claim to originality. St. Nicholas, Newcastle, and the High Church, Edinburgh, are its prototypes.

486. The Monument of London is original, notwithstanding columns of this sort had been previously erected. Its total expense was 8856*l.*, and it was commenced in 1671, completed in 1677. The height is 202 ft.; hence it is loftier than any of the historical columns of the ancients. The pedestal is about 21 ft. square, standing on a plinth 6 ft. wider. The lower diameter of the column on the upper part of the base is 15 ft., and the shaft incloses a staircase of black marble, consisting of 345 steps. It was fluted after the work was carried up. The quantity of Portland stone whereof it is composed is 28,196 cubic feet. The Antonine column at Rome is 175, and that of Trajan 147 ft. high. That erected by Arcadius at Constantinople, when perfect, was of the same height as that last mentioned. The structure of which we are speaking loses much by its situation, which has neither been improved nor deteriorated by the streets consequent on the rebuilding of London Bridge: and though it cannot compete with the Trajan column in point of intrinsic beauty, it is, nevertheless, an exquisite and well-proportioned work, and seems much better calculated with propriety to record the object of its erection, than the other is to be the monument of a hero. In these days, it is singular to see that no other mode than the erection of a column could be found to record the glorious actions of a Nelson. Such was the poverty of taste that marked the decision of the committee to whom that object was most improperly entrusted.

487. Among the works of Wren not to be passed without notice is the Library of Trinity College, Cambridge. It is one of his finest productions, and one with which he himself was well satisfied. It consists of two orders; a Doric arcade below, open to a basement supported by columns, which has a flat ceiling, exceedingly convenient as an ambulatory, and itself simple and well proportioned. The principal story is decorated with three-quarter columns of the Ionic order, well proportioned. From their volutes, festoons are pendent, and the key-stones of the windows are carved into cherubs' heads, &c. This is the elevation towards Nevill's Court; that towards the garden has three Doric doors below, but above is without columns or pilasters in the upper stories. Without ornament, it is not the less graceful and imposing. The interior, as a single room, is designed with great grandeur and propriety.

488. We cannot further in detail continue an account of the works of this extraordinary architect, but shall now proceed to submit a list of his principal works, together with a catalogue of those of his principal churches whose estimates exceeded the cost of 5000*l.*

	Begun.	Completed.
Palace at Greenwich, for Charles II.	1663	
Theatre at Oxford	1668	1669
The Monument	1671	1677
Temple Bar	1670	1672
St. Paul's Cathedral	1675	1710
Library at Trinity College, Cambridge	1679	
Campanile at Christ Church, Oxford	1681	1682
Ashmolean Library	1682	
Palace at Winchester	1683	Unfinished.
College of Physicians	1689	
College at Chelsea	1690	
Palace at Hampton Court	1690	1694
Towers of Westminster Abbey	1696	
Greenwich Hospital	1698	1703

Churches: —

	Time of erection.	Cost.		
Allhallows the Great	1697	5,641*l.*	9*s.*	9*d.*
Allhallows, Lombard Street	1694	8,058	15	6
St. Andrew Wardrobe	1692	7,060	16	11
St. Andrew, Holborn	1687	9,000	0	0
St. Antholin	1682	5,685	5	10
St. Bride	1680	11,430	5	11
Christ Church, Newgate Street	1687	11,778	9	6
St. Clement Dane's	1680–82	8,786	17	0
St. Dionis Backchurch	1674–84	5,737	10	8
St. Edmund the King	1690	5,207	11	0
St. Lawrence Jewry	1677	11,870	1	9
St. James, Garlick Hill	1683	3,357	10	8
St. James, Westminster	*circa* 1689	8,500	0	0
St. Michael Royal	1694	7,555	7	9
St. Martin's, Ludgate	1684	5,378	9	7
St. Margaret, Lothbury	1690	5,340	8	1
St. Mary, Somerset	1695	6,579	18	1
St. Mary, Aldermanbury	1677	5,237	3	6
St. Mary le Bow	1673	8,071	18	1
———— The steeple	1680	1,388	8	7
St. Nicholas, Coleabbey	1677	5,042	6	11
St. Olave Jewry	1673	5,580	4	10
St. Peter, Cornhill	1681	5,647	8	2
St. Swithin's, Cannon Street	1679	4,687	4	6
St. Magnus, London Bridge	1676	9,579	18	10

489. We must here close our account of Wren. Those of our readers who desire further information on the life and works of this truly great man will do well to consult the *Parentalia, or Memoirs of the Family of the Wrens*, compiled by his son, and published by his grandson Stephen Wren. Fol. Lond. 1750.

490. Among the architects of Wren's time, there was a triad of amateurs who would have done honour to any nation as professors of the art. The first of these was Henry Aldrich, D.D., Dean of Christ Church, Oxford, who died in 1710. He was attached to the Venetian school, as we may see in the three sides of Peckwater quadrangle, and the garden front of Corpus Christi College, a façade which for correct taste is not surpassed by any edifice in Oxford. The second of these amateurs was Dr. Clarke, one of the Lords of the Admiralty in the reign of Queen Anne. This distinguished amateur sat for Oxford in fifteen sessions. The Library of Worcester College, to which he bequeathed his valuable architectural collection of books and MSS., was from his design. He built the library at Christ Church. The third was Sir James Burrough, Master of Caius College, Cambridge; by whom, in 1703, the chapel of Clare Hall in that University was beautifully designed and executed.

491. We now approach the works of a man who, whatever some have thought of them, has a stronger claim on our notice as an inventor than any of his predecessors. It must be anticipated that we allude to Sir John Vanbrugh. Upon no other artist has Walpole delivered criticisms more unworthy of himself, nor is there any one of whose genius he had less capacity to appreciate the powers. The singular mind of Vanbrugh was distracted by control: his buildings are the result of a combination of forms and anticipation of effects, originating solely from himself; effects which none before had seen nor

contemplated. As a wit, he was inferior to none that levelled its shafts at him, and hence his novel compositions in architecture became among the professed critics of the day so much the more an object of derision, as, in their puny notions, his only assailable point. Attacked from party feeling, the public allowed itself to be biassed by epigrams and smart verses from the pens of Pope and Swift; and when the former, in his fourth epistle, in allusion to Vanbrugh's works, exclaims, —

> "Lo! what huge heaps of littleness around,
> The whole a laboured quarry above ground," —

he little thought he was leaving to posterity a record of his consummate ignorance of art, and of his total insensibility to grandeur, in all that relates to composition in architecture.

492. The opinion of Sir Joshua Reynolds first enlightened the public upon the thitherto condemned works of this extraordinary architect. "I pretend," says Reynolds, in his fifth discourse, "to no skill in architecture. I judge now of the art merely as a painter. When I speak of Vanbrugh, I speak of him merely on our art. To speak, then, of Vanbrugh in the language of a painter, he had originality of invention, he understood light and shadow, and had great skill in composition. To support his principal object, he produced his second and third groups of masses; he perfectly understood in *his* art what is most difficult in ours, the conduct of the backgrounds by which the design and invention is (are) set off to the greatest advantage. What the background is in painting is the real ground upon which the building is erected; and as no architect took greater care that his work should not appear crude and hard, — that is, that it did not abruptly start out of the ground, without expectation or preparation, — this is the tribute which a painter owes to an architect who composes like a painter." The testimony of Mr. Payne Knight, a person of a taste highly refined and cultivated, in his *Principles of Taste*, is another eulogium on the works of this master. And again we have the concurrence therein of another able writer on these subjects, who, though frequently at variance in opinion with Mr. Knight, thus expresses himself in his *Essay on the Picturesque*, vol. ii. p. 211.: "Sir J. Reynolds is, I believe, the first who has done justice to the architecture of Vanbrugh, by showing it was not a mere fantastic style, without any other object than that of singularity, but that he worked on the principles of painting, and that he has produced the most painter-like effects. It is very probable that the ridicule thrown on Vanbrugh's buildings, by some of the wittiest men of the age he lived in, may have in no slight degree prevented his excellencies from being attended to; for what has been the subject of ridicule will seldom become the object of study or imitation. It appears to me, that at Blenheim, Vanbrugh conceived and executed a very bold and difficult design, that of uniting in one building the beauty and magnificence of the Grecian architecture, the picturesqueness of the Gothic, and the massive grandeur of a castle; and that, in spite of many faults, for which he was very justly reproached, he has formed, in a style truly his own, and a well-combined whole, a mansion worthy of a great prince and warrior. "His first point appears to have been massiveness, as the foundation of grandeur: then, to prevent the mass from being a lump, he has made

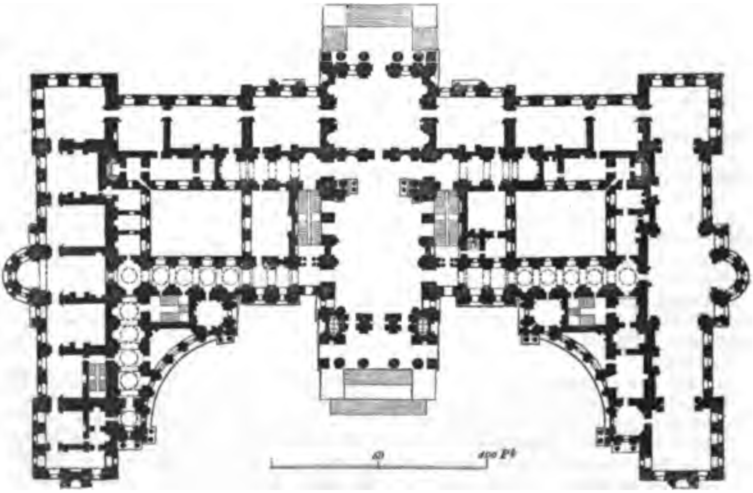


Fig. 215. PLAN OF BLENHEIM.

various bold projections of various heights, which seem as foregrounds to the main building; and, lastly, having been probably struck with a variety of outline against the sky in many Gothic and other ancient buildings, he has raised on the top of that part where the slanting roof begins in any house of the Italian style, a number of decorations of various characters. These, if not new in themselves, have, at least, been applied and combined by him in a new and peculiar manner, and the union of them gives a surprising splendour and magnificence, as well as variety, to the summit of that princely edifice. The study, therefore, not the imitation, might be extremely serviceable to artists of genius and discernment."

493. Vanbrugh's principal work was Blenheim (whereof we give, in *figs.* 215. and 216., the plan and principal elevation), a monument of the victories of Marlborough raised by a grateful nation. Its length on the north front from one wing to the other is 348 ft. The internal dimensions of the library are 130 by 32 ft. The hall is perhaps small compared with the apartments to which it leads, being only 53 ft. by 44, and 60 ft. high.

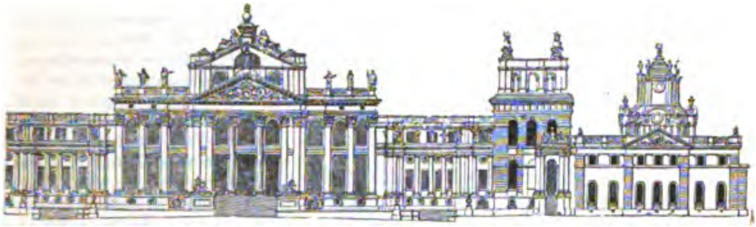


Fig. 216. ELEVATION OF BLENHEIM.

494. The execution of his design for Castle Howard, in Yorkshire, was commenced in 1702, and, with the exception of the west wing, was completed by him. The design possesses much greater simplicity than that of Blenheim. There is a portico in the centre, and a cupola of considerable height and magnitude. The galleries, or wings, are flanked by pavilions. The living apartments are small; but for the comfort and convenience of the house, as an habitation, many improvements have been made since the time of Vanbrugh

495. At Eastbury, in Dorsetshire, he built a spacious mansion for Mr. Doddington. The front of it, with the offices, extended 370 ft. We regret to say that it was taken down by the first Earl Temple, about the middle of the last century.

496. King's Weston, near Bristol, erected for the Honourable Edward Southwell. A beautiful feature in the house is the grouping of the chimneys, in which practice no artist has surpassed, nor perhaps equalled, him. This house is not, however, a favourable specimen of our architect's powers.

497. In the front which he executed to Grimsthorpe, in Lincolnshire, he indulged himself in an imitation of Blenheim and Castle Howard. The hall here is of noble dimensions, being 110 ft. in length, and 40 ft. in height, surmounted by a cupola.

498. Charles Howard, the third Earl of Carlisle, Deputy Earl Marshal in 1703, appointed Vanbrugh, Clarenceux king of arms, over the heads of all the heralds, who remonstrated, without effect, against the appointment. The cause of such an extraordinary promotion is supposed to have had its origin in the Earl's satisfaction with the works at Castle Howard. It was, however, altogether unjustifiable, for Vanbrugh was, from all accounts, totally ignorant of heraldry. He held the situations of surveyor of the works at Greenwich Hospital, comptroller general of the works, and surveyor of the gardens and waters. Though perhaps out of place in a history of architecture, we cannot resist the opportunity of mentioning that our artist was a dramatist of genius. The Relapse, The Provoked Wife, The Confederacy, and Æsop, according to Walpole, will outlast his edifices. He died at Whitehall, March 26. 1726. Vanbrugh can hardly be said to have left a legitimate follower; he formed no school. Archer, indeed, attempted to follow him, and seems the only one of his time that could appreciate the merit of his master. But he was too far behind him to justify our pausing in the history of the progress of British architecture to say more than that his best works are Heythrop, and a temple at Wrest. St. Philip's Church at Birmingham is also by him. "A chef d'œuvre of his absurdity," says Dallaway, "was the church of St. John's, Westminster, with four belfries," a building which has not inaptly been likened to an elephant on his back, with his four legs sprawling in the air.

Sect. VIII.

GEORGE I.

499. Though the example of Wren was highly beneficial to his art, he does not seem to have been anxious to propagate his doctrines by precepts, for he had but one pupil who deserves a lengthened notice. That pupil was Nicholas Hawksmoor, who, at the age of eighteen, became the disciple of Sir Christopher, "under whom," says Walpole, "during life, and on his own account after his master's death, he was concerned in erecting many public edifices. Had he erected no other than the church of St. Mary Woolnoth, Lombard Street, his name would have deserved with gratitude the remembrance of all lovers of the art. This church has recently (on the opening of King William Street) been unfortunately disfigured on its southern side by some incompetent bungler on whom the patronage of the churchwarden lucklessly fell. Such is the fate of our public buildings in this country. The skill displayed by Hawksmoor in the distribution and design of St. Mary Woolnoth is not more than rivalled by the best productions of his master and instructor. We here give, in *figs.* 217. and 218., a half section, elevation, and plan of it. It was commenced in 1716, and finished in 1719. Not until lately was it seen to advantage. Lombard Street, in which it still partly stands, was narrow, and its northern elevation, the only one till lately properly seen, required, from its aspect, the boldest form of detail to give it expression, because of its being constantly in shade, and therefore experiencing no play of light except such as is reflected. This is composed with three large semicircular rusticated niches, each standing on a lofty rusticated pedestal, relieved with blank recesses, which are repeated in the intervals below between the niches. The whole stands on a basement, whose openings, of course, correspond to those above. The niches in the recesses are decorated with Doric columns on pedestals, and the top of the entablature of the order is level with the springing of each niche head running through on each side, so as to form an impost. The front is crowned with a block cornice, continued round the building, and the central part of the northern front is surmounted by a balustrade. We are not prepared to maintain that the whole of the details are in the purest taste; but the masses are so extremely picturesque, and so adapted to the circumstances of the aspect and situation, that their faults are forgotten. Not so the interior, which needs no apology. It is a combination of proportions, whose beauty cannot be surpassed in any similar example. The plan is nearly a square, whose north-west and south-west angles are truncated at angles of forty-five degrees, for the introduction of stairs. The leading lines are an inscribed square whose sides are equal to two thirds of the internal width, the remaining sixth on each side being assigned to the intercolumniations between the columns and the pilasters on the internal walls. The columns, twelve in number, are placed within the sides of the inscribed square, and at the angles are coupled at intervals of one diameter. The order is Corinthian; the columns are fluted, and crowned by an enriched entablature one quarter of their height. The space thus enclosed by the columns continues in a clerestory above, pierced on the four sides by semicircular windows, whose diameters are equal to one of the wide intercolumniations below. The height of this, including its entablature, is one half that of the lower order; thus, with its pedestal, making the total height of the central part of the

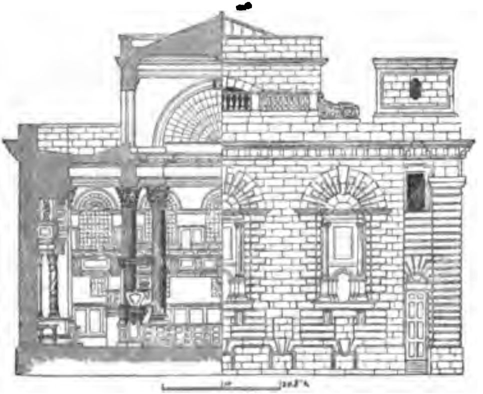


Fig. 217. HALF ELEVATION HALF SECTION OF ST. MARY WOOLNOTH.

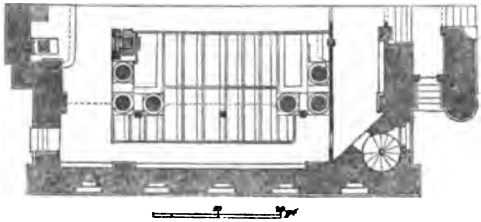


Fig. 218. PLAN OF ST. MARY WOOLNOTH.

church, equal to its extreme width. A sesquialteral proportion is thus obtained in section as well as plan. The eastern end is recessed square for an altar piece, and arched with a semicircular ceiling enriched with caissons. The galleries are admirably contrived, and in no way interfere with the general effect, nor destroy the elegance and simplicity of the design. The ceilings throughout are horizontal, and planned in compartments, whose parts are enriched. As regards construction, there is a very unnecessary expenditure of materials, the ratio of the superficies to the points of support being 1:0·263. Hawksmoor was not so happy in the church of St. George's, Bloomsbury, in which he has really made King George I. the head of the church by placing him on the top of the steeple, which we must, with Walpole, term a master-stroke of absurdity. But many parts of the building are highly deserving the attention of the student; and if the commissioners for new churches in these days had been content with fewer churches constructed solidly, like this, instead of many of the pasteboard excrescences they have sanctioned, the country, instead of regretting they ever existed, which will at no very remote period be the case, would have owed them a deep debt of gratitude. The only gratification we have on this point is, that a century, and even less, will close the existence of a large portion of them. Hawksmoor was deputy surveyor of Chelsea College and clerk of the works at Greenwich, and in that post was continued by William, Anne, and George I., at Kensington, Whitehall, and St. James's. Under the last named he was first surveyor of all the new churches and of Westminster Abbey, from the death of Sir Christopher Wren. He was the architect of the churches of Christ Church, Spitalfields, St. George, Middlesex, and St. Anne, Limehouse; rebuilt some part of All Souls, Oxford, particularly the new quadrangle completed in 1734, and was sole architect of the new quadrangle at Queen's. At Blenheim and Castle Howard he was associated with Vanbrugh, and at the last-named place was employed on the mausoleum. Among his private works was Easton Neston, in Northamptonshire, and the restoration to perpendicularity, by means of some ingenious machinery, of the western front of Beverley Minster. He gave a design for the Radcliffe Library at Oxford, and of a stately front for Brazenose. His death occurred on the 25th of March, 1736, at the age of near seventy.

500. Those acquainted with the condition of the country will be prepared to expect that the arts were not much patronised by George I. The works executed during his reign were rather the result of the momentum that had been imparted previous to his accession than of his care for them; and it is a consolation that the examples left by Inigo Jones had an effect that has in this country never been entirely obliterated, though in the time of George III., such was the result of fashionable patronage and misguided taste, that the Adamses had nearly consummated a revolution. That reign, however, involved this country in so many disasters that we are not surprised at such an episode.

501. After the death of Hawksmoor, succeeded to public patronage the favourite architect of a period extending from 1720 to his death in 1754, whose name was James Gibbs, a native of Aberdeen, where he first drew breath in 1683. Though he had no claims to the rank of exalted genius, he ought not to have been the object of the flippant criticism of Walpole, whose qualifications and judgment were not of such an order as to make him more than a pleasant gossip. He certainly had not sufficient discernment properly to estimate the talents of Gibbs's works. Every critic knows how easily phrases may be turned and antitheses pointed against an artist whom he is determined to set at nought; of which we have before had an instance in the case of Sir John Vanbrugh; and we shall not here further dilate upon the practice. We will merely observe, that on the appearance of any work of art the majority of the contemporary artists are usually its best judges, and that in ninety-nine cases out of a hundred the public afterwards sanction their decision; and we will add, in the words of old Hooker, that "the most certaine token of evident goodnesse is, if the generall perswasion of all men doe so account it;" and again, "although wee know not the cause, yet this much wee may know, that some necessarie cause there is, whensoever the judgement of all men generally or for the most part runne one and the same way." We do not, therefore, think it useful in respect of an artist of any considerable talent to repeat a criticism more injurious to the writer than to him of whom it was written.

502. The church of St. Martin's in the Fields is the most esteemed work of our architect. It was finished in 1726, as appears from the inscription on the frieze, at the cost of 33,017*l.* 9*s.* 3*d.* The length of it, including the portico, is twice its width, one third whereof, westward, is occupied by the portico and vestibule. The portico is hexastyle, of the Corinthian order, and surmounted by a pediment, in whose tympanum the royal arms are sculptured. The intercolumniations are of two diameters and a half, and the projection of the portico of two. Its sides are flanked by antæ in their junction with the main building, one diameter and a half distant from the receiving pilaster. The north and south elevations are in two stories, separated by a fascia, with rusticated windows in each. Between the windows the walls are decorated with pilasters of the same dimensions as the columns of the portico, four diameters apart; but at the east and west ends these elevations are marked by insulated columns coupled with antæ. The flanks are connected with the

prevailing lines in the portico by columns placed on the walls, recessed for the purpose, and coupled with antæ, whereby a play of light is produced, which imparts great effect to the other parts. The interior is divided into three unequal portions by a range on each side of four Corinthian columns, and two pilasters placed on pedestals, raised to the height of the pewing. From their insulated entablatures rises an elliptical ceiling, covering what may be called the nave. This ceiling is formed by arcs doubleaux, between which the vault is transversely pierced in the spaces above the intercolumniations by semicircular arches springing from the top of the entablature of each column. Over what may be called the aisles, from the entablatures of the columns, semi-circular arches are turned and received northward and southward on consoles attached to the walls, and by their junction with the longitudinal arches from column to column pendentives are evolved, and thereby are generated small flat domes over the galleries. The altar is recessed from the nave in a large niche formed by two quadrants of circles, whose radius is less than one fourth of the whole width of the niche. It is vaulted semi-elliptically. Galleries are introduced on the north, south, and west sides of the church. On the two former sides they extend from the walls to the columns, against which the continuity of their mouldings is broken. The interior is highly decorated, perhaps a little too theatrically for the sombre habits of this country; but its effect is, on the whole, extremely light and beautiful. The tower and spire are, as in all the English churches of the Italian style, a sad blemish; but the taste of the day compelled their use, and we regret that the clergy still persist in considering them requisites. The length from the front upper step to the east wall (inclusive) is 159 ft. 6 in., and the breadth from north to south 79 ft. 4 in. The total area of the church is 12,669 ft., whereof the points of support occupy 2803 ft. The ratio, therefore, of the former to the latter is a 1 : 0·220, from which we may infer that the edifice exhibits no very extraordinary constructive skill. The span of the roof (*fig.* 696.), which is of the common king-post form, is 38 ft. Gibbs, unlike Wren, does not appear to have been guided in his leading proportions of this work by a series of ratios. The only point in which we perceive an approximation to such a system is in the length from the plinths of the columns of the portico, being just double the width of the church measured at the same level. The portico is well designed, and hitherto has not been equalled in London.

503. In the church of St. Mary le Strand, Gibbs was not so successful. There is no portion of its space on which the eye rests with pleasure. It is cut up into littlenesses, which, though not individually offensive, destroy all repose or notion of mass in the fabric. He built the new church at Derby, and executed some works at King's College, Cambridge, which last were not calculated to raise his reputation; but in the senate house of that university, he was more successful. In the Radcliffe Library at Oxford, his fame was maintained. It was completed in 1747, and thereon he was complimented with the degree of Master of Arts. This library is on the plan circular in general form, and rises in the centre of an oblong square, 370 ft. long, by 110 in width. Its cupola is 100 ft. in diameter, and 140 ft. high. It possesses no features of striking beauty, and yet is a most valuable addition to the distant view of Oxford, from whatever point of view it is seen. The interior is pleasing, and the distribution good. The books are disposed in two circular galleries, round a large central area. A description of this celebrated building was published with plans and sections, fol. 1747. Gibbs was the architect also of St. Bartholomew's Hospital. In 1728, he published a large folio volume of designs, including several of his works.

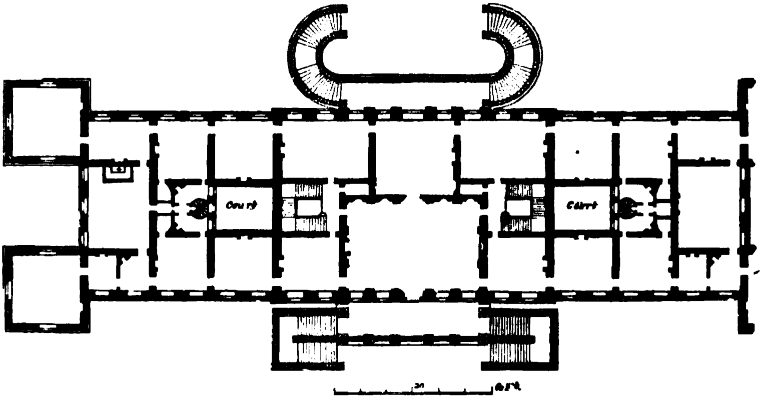


Fig. 219. PLAN OF WANSTEAD HOUSE.

504. Some works of considerable importance were erected during the reign of George I., by a countryman of the last-named architect, Colin Campbell, who is, however, more esteemed for three volumes he published of the principal buildings in England, under the name of the *Vitruvius Britannicus*. Of this work Lord Burlington was the original projector and patron. Afterwards, in 1767 and 1771, it was continued in two volumes, under the superintendence of Wolfe and Gandon, two architects of considerable reputation. Campbell's talents were not of a very high order, though Mereworth, in Kent, an imitation of the Villa Capra, built for Mildmay Earl of Westmorland, and Wansted House, in Essex, built in 1715, and pulled down in 1815, the latter especially, entitle him to be considered an artist of merit. Foreigners, whilst this last was in existence, always preferred it to any other of the great mansions of the country. Gilpin says of it, "Of all great houses, it best answers the united purposes of grandeur and convenience. The plan is simple and magnificent. The front extends 260 ft. A hall and saloon occupy the body of the house, forming the centre of each front. From these run two sets of chambers. Nothing can exceed their convenience. They communicate in one grand suite, and yet each, by the addition of a back stair, becomes a separate apartment. It is difficult to say whether we are better pleased with the grandeur and elegance without, or with the simplicity and contrivance within. Dimensions: Great hall, 51 ft. by 36; ball room, 75 by 27; saloon, 30 ft. square." As the building no longer exists, we give, in *figs.* 219. and 220., a ground plan and elevation of it. Campbell was surveyor of the works of Greenwich Hospital, and died in 1734.

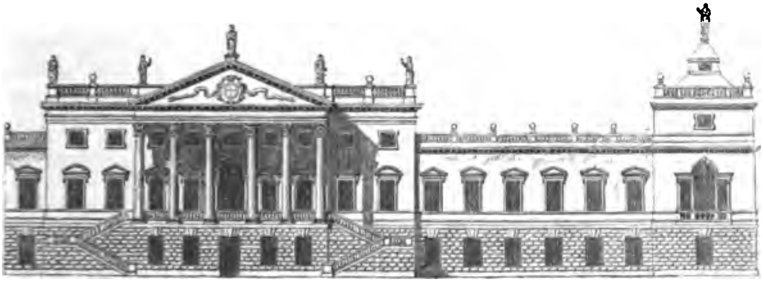


Fig. 220. ELEVATION OF WANSTEAD HOUSE.

505. The church at Greenwich, and a very large mansion at Blackheath for Sir Gregory Page, in the latter whereof much is said to have been borrowed from Houghton, but which has many years since disappeared, were, about 1718, erected by John James, of whom very little more is known than these works, and, in London, the churches of St. George, Hanover Square, and St. Luke's, Middlesex, the latter whereof has a fluted obelisk for a steeple. We ought, besides, to mention that he was employed by the Duke of Chandos, at Cannons, another building no longer in existence, and showing the frail tenure upon which an architect's reputation and fame is held. At the latter place, however, it may be questioned whether the remark strictly applies, inasmuch as he is said to have therein set taste and expense equally at defiance.

Sect. IX.

GEORGE II.

506. We do not altogether agree with Walpole in the observation that architecture resumed all her rights during this reign, though there is no doubt that the splendid (for the time) publications of Palladio, Jones, and examples of the antique recalled the taste of artists and their patrons the public. Men of genius were doubtless found to support the arts by their practice, and some high-minded patrons to encourage them in their labours. "Before," observes Walpole, "the glorious close of a reign that carried our arms and victories beyond where Roman eagles ever flew, ardour for the arts had led our travellers to explore whatever beauties of Grecian or Latin skill still subsisted in provinces once subjected to Rome, and the fine additions, in consequence of those researches, have established the throne of architecture in Britain while itself languishes in Rome."

507. Among the earliest of the architects of this reign was Thomas Ripley, a native of Yorkshire, at whom Pope sneers in the lines —

> "Who builds a bridge that never drove a pile?
> Should Ripley venture, all the world would smile."
> *Imit. Horace*, Ep. II. S. 186.

Ripley, it must be confessed, failed at the Admiralty, which was afterwards veiled by Mr. Adam's beautiful skreen since cruelly "cheated of its fair proportions" by the late architect to that Board, in order to make two coach entrances, which might, with the exercise of a little ingenuity, have been managed without defacing the design. It is difficult, now, to decide the exact share that Ripley had in the house for Lord Orford, at Houghton, for which Campbell appears to have furnished the original design. Walpole, whom we may presume to have known something about the matter, says they were much improved by Ripley. He published them in two volumes, folio, 1755—60. It is to be regretted that scarcely a single line of Pope, in matters of taste relative to the artists of his day, is of the smallest worth, so much did party and politics direct the shafts of the poet's malice. The plain truth is, that Ripley was the rival of Kent, the favourite of Lord Burlington, whose patronage it was absolutely necessary to enjoy before he could ensure the smiles of Pope. Ripley was comptroller of the Board of Works, and died in 1758.

508. Henry Herbert, Earl of Pembroke, an amateur of this reign, cannot pass unnoticed in the History of its Architecture. He much improved Wilton, where he built the Palladian Bridge; and it is highly honourable to his memory that, owing to his exertions, the qualifications of Labelye for building Westminster Bridge were acknowledged in opposition to Hawksmoor and Batty Langley, the latter of whom was an ignorant pretender. Of this bridge Earl Henry laid the first stone in 1739, and the last in 1747. His works, besides those at Wilton, were, the new lodge in Richmond Park, the Countess of Suffolk's house at Marble Hill, Twickenham, and the Water House at Lord Orford's Park at Houghton. He died in 1751.

509. Before advancing our history another step, we have to notice another nobleman, whom to enrol among the number of her artists is an honour to England; and in speaking of Richard Boyle, the third Earl of Burlington and fourth Earl of Ossory, we so entirely agree in Walpole's eulogy of him, that we shall not apologise for transcribing it from that author's pages: — "Never was protection and great wealth more generously and judiciously diffused than by this great person, who had every quality of a genius and an artist, except envy. Though his own designs were more chaste and classic than Kent's, he entertained him in his house till his death, and was more studious to extend his friend's fame than his own." Again, he continues, "Nor was his munificence confined to himself and his own houses and gardens. He spent great sums in contributing to public works, and was known to chuse that the expense should fall on himself, rather than that his country should be deprived of some beautiful edifices. His enthusiasm for the works of Inigo Jones was so active that he repaired the church of Covent Garden, because it was the production of that great master, and purchased a gateway at Beaufort Gardens, in Chelsea, and transported the identical stones to Chiswick with religious attachment. With the same zeal for pure architecture, he assisted Kent in publishing the designs for Whitehall, and gave a beautiful edition of the 'Antique Baths, from the Drawings of Palladio,' whose papers he procured with great cost. Besides his works on his own estate, at Lonsborough, in Yorkshire, he new-fronted his house in Piccadilly, built by his father, and added the great colonnade within the court." This liberal-minded nobleman gave the credit of this design to Kent, though, as Kent did not return from Italy before 1729, it is certain that architect could have had little to do with it. His villa at Chiswick, now that of the Duke of Devonshire, was an original design, and not, as is generally supposed, an imitation of Palladio's Villa Capra at Vicenza. It was, however, too much in the Italian taste to be suitable to an English climate or to English comforts; hence its great external beauty extracted from Lord Chesterfield the well-known verses —

> "Possessed of one great house of state,
> Without one room to sleep or eat,
> How well you build let flatt'ry tell,
> And all mankind how ill you dwell."

Lord Hervey also sported his little wit upon this little bijou, which its subsequent additions have not much improved, saying "that it was too small to inhabit, and too large to hang one's watch in."

510. The dormitory of Westminster School and the Assembly Room at York are beautiful examples of the great powers of Lord Burlington; but the house for Lord Harrington at Petersham, the Duke of Richmond's at Whitehall (pulled down), and General Wade's house in Great Burlington Street were not well planned, the latter especially, on which it was said by Lord Chesterfield, on account of its beautiful front, that "as the general could not live in it to his ease, he had better take a house over against it, and look at it." The Earl of Burlington was born in 1695, and died in 1753.

511. William Kent, a native of Yorkshire, where he was born in 1685, if he did not advance the art, was at least far from retarding or checking any progress it seemed likely

to make. Kent was a painter as well as an architect, though as the former very inferior to the latter; and to these accomplishments must be added those of a gardener, for he was the father of modern picturesque gardening. Kent's greatest, and, out of many, also his best work, was Holkham, in Norfolk, for the Earl of Leicester, the plan and elevations whereof were published in folio, 1761, by the late Mr. Brettingham, who had the unparalleled assurance to send them to the world as his own. The noble hall of this building, terminated by a vast flight of steps, produces an effect unequalled by anything similar to it in England. During, and, indeed, previous to, Kent's coming so much into employment, a great passion seems to have existed with the architects for ill-shaped, and, perhaps, almost grotesque, urns and globes, on every part where there was a resting-place for them. Kent not unfrequently disfigured his works in this way, but more especially so at the beginning of his career. The pile of building in Margaret Street, which will shortly have to make way for part of the new parliament houses, now, however, containing the law courts, a house at Esher for Mr. Pelham, the Horse Guards, and other buildings, which it is needless here to particularise, were erected under the designs of Kent, upon whom unbounded liberality and patronage were bestowed by Lord Burlington during the life of this artist, which terminated in 1748.

512. About 1733 appeared, we believe, the last of the stone churches with steeples, which the practice of Wren had made common in this country; this was the church of St. Giles's in the Fields, erected by Henry Flitcroft. The interior is decorated with Ionic columns resting on stone piers. The exterior has a rusticated basement, the windows of the galleries have semicircular heads, and the whole is surmounted by a modillion cornice. The steeple is 165 feet high, consisting of a square tower, the upper part decorated with Doric pilasters; above, it is formed into an octagon on the plan, the sides being ornamented with three quarter Ionic columns supporting a balustrade and vases. Above this rises an octangular spire. Besides this, Flitcroft erected the church of St. Olave, Southwark, and the almost entire rebuilding of Woburn Abbey was from the designs and superintendence of that master, who died in 1769.

513. During the reign under our consideration, the city of Bath may be said to have almost arisen from the designs of Wood, who built Prior Park for Mr. Allen, the friend of Pope, and Buckland was erected by him for Sir John Throckmorton. Wood died in 1754, To him and to his scholars Bath is indebted for the designs of Queen Square, the Parades, the Circus, the Crescent, the New Assembly Room, &c. The buildings of this city possess various degrees of merit, but nothing so extraordinary as to call for more than the mere notice of them. We are by no means, for instance, disposed to agree with Mitford, who reckons the crescent of Bath among "the finest modern buildings at this day existing in the world!"

Sect. X.

GEORGE III.

514. Though the works of the architects about to follow, belong partially to the preceding reign, they are only properly to be noticed under that of George III. Without a lengthened account of them, we commence with the mention of the name of Carr of York, who was much employed in the northern counties, where he built several noble residences, particularly that for Mr. Lascelles, afterwards Lord Harewood, and a mausoleum in Yorkshire for the late Marquis of Rockingham. Paine was engaged at Worksop Manor, Wardour Castle, and Thorndon; and Hiorne, whose county sessions-house and prison at Warwick exhibit considerable genius, was a promising artist, prematurely cut off. His talent was not confined to the Italian style, as may be learnt from reference to the church at Tetbury in Gloucestershire, and a triangular tower in the Duke of Norfolk's park at Arundel.

515. At a early part of the reign of George III., architecture was cultivated and practised here with great success by Robert Taylor, afterwards knighted. His best compositions were designed with a breadth and intimate knowledge of the art, that prove him to have been abundantly acquainted with its principles. That he was not always successful, the wings of the Bank, now removed, were a proof. Of his works sufficient would remain to corroborate our opinion, if only what is now the Pelican Office in Lombard Street existed. We believe it was originally built for Sir Charles Asgill, and ruined by the directors of the Pelican when they took to the place. There are, however, also to attest the ability of Sir Robert Taylor, Sir Charles Asgill's villa at Richmond, and his own house in Spring Gardens. After his visit to Italy he commenced his practice in sculpture, in which branch of the arts he has left monuments in Westminster Abbey and elsewhere; but he afterwards devoted himself to architecture alone. Among his works were a dwelling house for Sir P. Taylor,

near Portsdown Hill, a house in Piccadilly for the Duke of Grafton, a mansion in Herts for Lord Howe; Stone Buildings, Lincoln's Inn; Ely House, Dover Street; a very clever composition, Sir John Boyd's at Danson, near Shooter's Hill; the beautiful bridge at Henley on Thames, and Lord Grimstone's at Gorhambury. He had for some time a seat at the Board of Works, was surveyor to the Admiralty, the Bank, and other public bodies. His reputation was unbounded, and met with reward from the public. Sir Robert Taylor died in 1788 at the age of seventy-four.

516. Cotemporary with the last-named artist, was one to whom the nation is indebted for first bringing it to an intimate acquaintance with the works of Greece, to which he first led the way. The reader will, of course, anticipate us in the name of James Stuart, who began his career as a painter. After some time passed in Greece, he, in conjunction with Nicholas Revett, about the year 1762, published the well-known *Antiquities of Athens*, from which he acquired the soubriquet of *Athenian*. The public taste was purified by a corrected knowledge of the buildings of Greece, especially in respect of the form, composition, and arrangement of ornament; but we doubt whether mischief was not for a time induced by it, from the absurd attempt, afterwards, to adapt, without discrimination, the pure Greek porticoes of the temples of Greece to public and private buildings in this country, often with buildings with which they have no more natural relation than the interior arrangement of a church has with that of a theatre. The architects of our own time seem, however, at last to be aware of the impossibility of applying with success the forms of Grecian temples to English habitations; and a better system has been returned to, that of applying to every object a character suitable to the purposes of its destination. We consider Stuart's best work the house, in St. James's Square, which he built for Lord Anson. Among other works, he executed Belvedere, in Kent, for Lord Eardley; a house for Mrs. Montague, in Portman Square; the chapel and infirmary of Greenwich Hospital; and some parts of the interior of Lord Spencer's house, in St. James's Place. Stuart died in 1788, at the age of seventy-five. His *collaborateur*, Revett, shared with him a portion of the patronage of the public. He survived him till 1804, when he died at the advanced age of eighty-two years. He was employed on the eastern and western porticoes of Lord De Spencer's house at West Wycombe, and on some temples. For Sir Lionel Hyde he built the church of Ayot St. Lawrence, Herts, the front whereto is a Doric portico crowned with a low Grecian pediment, and on each side an Ionic colonnade connects the centre with an elegant cenotaph. He also built a portico to the eastern front of Handlinch, in Wiltshire, for Mr. Dawkins.

517. The chasteness and purity which the two last-named architects had, with some success, endeavoured to introduce into the buildings of England, and in which their zeal had enlisted many artists, had to contend against the opposite and vicious taste brought by Robert Adam, a fashionable architect, whose eye had been corrupted by the corrupt taste of the worst time of Roman art. It can be scarcely believed, the ornaments of Diocletian's palace at Spalatro should have loaded our dwellings contemporaneously with the use among the more refined few of the exquisite exemplars of Greece, and even of Rome, in its better days. Yet such is the fact; the depraved compositions of Adam were not only tolerated, but had their admirers. It is not to be supposed that the works of a man who was content to draw his supplies from so vitiated a source will here require a lengthened notice. Yet had he his happy moments; and that we may do him strict justice, we not only mention, but present to the reader, in *figs*. 221. and 222., the ground plan and elevation of Kedlestone, in Derbyshire, which he erected for Lord Scarsdale. The detail of this is, indeed, not exactly what it ought to have been; but the whole is magnificently conceived, and worthy of any master. Adam died at the age of ninety-four, in 1792; and, besides the Adelphi, in the Strand, which he erected on speculation, he was engaged at Luton Park, in Bedfordshire, for the Earl of Bute; at Caenwood, near Hampstead, for Lord Mansfield; at Shelburne House, in Berkeley Square, now Lord Lansdowne's, well planned, but ill designed, a meagre affair; the disgraceful gateway at Sion, near Brentford; and on part of the Register Office at Edinburgh. None, however, would now do credit to a mere tyro in the art except the first named.

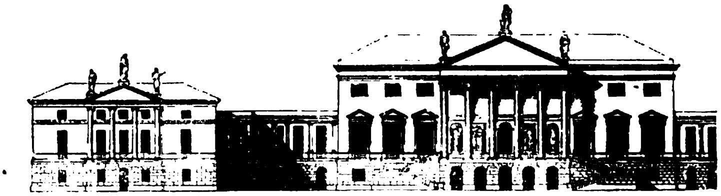


Fig. 221. ELEVATION OF KEDLESTONE.

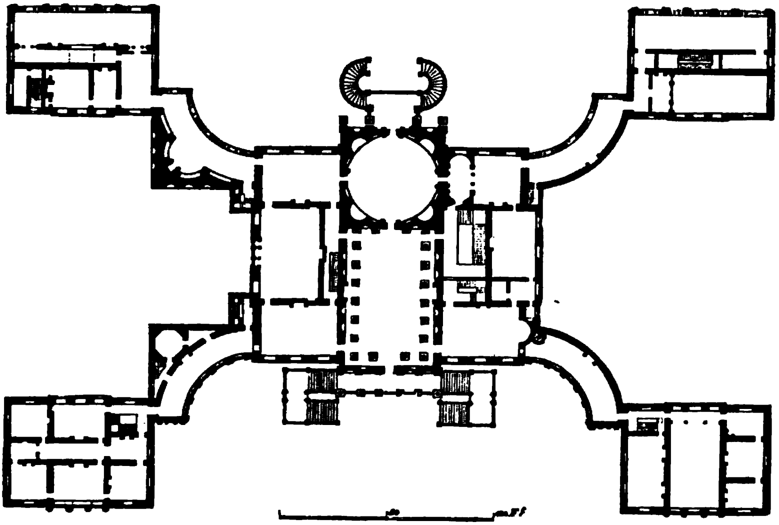


Fig. 222. PLAN OF KEDLESTONE.

518. Previous to the accession of George III. it had been considered by his tutors necessary to complete his education by the study requisite to give him some acquaintance with the art. We venerate the memory of that monarch as an honest good man, but are compelled to say that the experiment of inoculating him with a taste for it was unsuccessful, for during his reign all the *bizareries* introduced by Adam received no check, and seeing that Adam and Bute were both from the north, we are rather surprised that his education was not in this respect committed to the former instead of Sir William Chambers, whom, as one of the first architects of the day, it is incumbent upon us now to introduce. We believe that whatever was done to forward the arts, owes a large portion of its effect to that celebrated man; and it is probable, with the worthy motives that actuated the monarch, and the direction of his taste by that individual, much more would have been accomplished, but for the heavy and disastrous wars which occurred during his reign, and the load of debt with which it became burthened. The works of Chambers are found in almost every part of England, and even extended to Ireland; but we intend here chiefly to restrict ourselves to a short account of Somerset House, his largest work, in which, though there be many faults, so well did he understand his art, that it is a matter of no ordinary difficulty, and indeed requires hypercriticism, to find anything offensive to good taste in the detail.

519. This work was commenced in 1776, and stands on an area of 500 ft. in depth, and 800 ft. in width. The general interior distribution consists of a quadrangular court, 343 ft. in length, and 210 ft. in width, with a street or wide way running from north to south, on its eastern and western sides. The general termination towards the river is a terrace, 50 ft. wide, whose level is 50 ft. above that of the river, and this occupies the whole length of the façade in that direction. The front towards the Strand is only 135 ft. long. It is composed with a rustic basement, supporting ten Corinthian columns on pedestals, crowned by an attic, extending over the three central intercolumniations, flanked by a balustrade on each side. The order embraces two stories. Nine large arches are assigned to the basement, whereof the three central ones are open for the purpose of affording an entrance to the great court. On each side of them, these arches are occupied by windows of the Doric order, decorated with pilasters, entablatures, and pediments. The key stones are carved in alto-relievo, with nine colossal masks, representing the ocean, and the eight principal rivers of Great Britain. The three open arches of entrance before mentioned lead to a vestibule, which connects the Strand with the large quadrangular court, and serves also as the access to those parts of the building, till lately occupied by the Royal Academy, and on the opposite or eastern side to the Royal Society and the Society of Antiquaries, the entrances whereto are within the vestibule. This is decorated with columns of the Doric order, whose entablature supports a vaulted ceiling. The front of this pile of building towards the quadrangle, is 200 ft. in extent, being much more than the length of that towards the Strand; the style, however, of its decoration is correspondent with it, the principal variation being in the use of pilasters instead of columns, and in the

doors and windows. The front next the Thames is ornamented in a similar manner to that already described. It was originally intended that the extent of the terrace should have been 1100 ft. This last is supported by a lofty arcade, decorated towards the ends with coupled Tuscan columns, whose cornice is continued along the whole terrace. The edifice was at the time the subject of much severe criticism, and particularly from the pen of a silly engraver of the name of Williams, under the name of Antony Pasquin; but the censures he passed on it, the author being as innocent of the slightest knowledge of the art as most of the writing architectural critics of the present day, were without foundation, and have long since been forgotten.

520. In the year 1759, Sir W. Chambers published a Treatise on the decorative part of civil architecture, whereof it was the lot of the writer to publish an enlarged edition in 1825. This work, as far as it goes, still continues to be a sort of text-book for the student; but as it is merely what its title imports, without touching on the historical or practical parts of the art, it is so far incomplete. Chambers held the office of surveyor general, and died in 1796.

521. Among the architects of George III.'s reign, we must not forget Robert Mylne, the architect of Blackfriar's Bridge, constructed between 1760 and 1768; Holland, who erected Carlton House for George IV. when Prince of Wales, and Drury Lane Theatre, neither of which buildings now exists; Dance, the architect of Newgate, St. Luke's Hospital, and many buildings about the city of London, to whose corporation he was architect; and, lastly, Willey Reveley, a pupil of Chambers, who followed the steps of Stuart and visited Athens and the Levant. He was the editor of the third volume of the *Antiquities of Athens*, and died prematurely in 1799. He built the new church at Southampton, and offered some beautiful designs for the new baths at Bath, which, however, were not adopted. We have now concluded a general view of the history of the art, from its dawn in this country to the end of the reign of George III.; having enumerated the professors of later days most worthy to be recorded. Further we should not be able to pursue our inquiry without coming so into contact with our cotemporaries and their connections, that our office, if not dangerous and fearful, might be unpleasant, and we must here close. We regret we cannot think our national architecture advances in the same ratio that the facilities of study in the present day would indicate. This is not to be imputed so much to the professors of the art as to the way in which it is treated by Government and the public; witness the National Gallery, made a job by a minister for an incompetent artist. "It is a national, a social misfortune," says the late James Spiller, "that to the scientific study of this noble art, there is no reasonable, much less liberal encouragement. It is degraded and crushed under the most despicable spirit of calculation and parsimony!" If ever a deathblow was aimed at the art, that was done by the commissioners for building the recent new churches. What artist could hope to become celebrated under their pinching ordinances, competitions, and contracts, with their accompanying legal din and "smithery?" Far different was the conduct of those commissioners to whom Queen Anne entrusted the building of her churches, or their existence would have been matter only of history, a category that we are certain will apply, at the end of a century, to many of those of the present day.

BOOK II.

THEORY OF ARCHITECTURE.

CHAP. I.

ARITHMETIC AND ALGEBRA.

SECT. I.

INTRODUCTION.

522. THE abstract relations of quantity and figure ought to be thoroughly understood by the architect, that he may be able to prepare the designs which he has conceived, in a manner suitable for execution, and, when executed, to possess stability. The form and mechanical effect of each single block in a building depends on its position, and the form of one of its parts limits the forms of others. In groups of bodies, these limitations are still more perplexing; hence we must have recourse to the most easy and accurate means of ascertaining the practicable conditions which will produce the desired effect. To this end we propose to give a short and simple course of the elements of arithmetic and analysis, as our own experience informs us that occasions arise in the practice of architecture which require all the aid that science can afford. Those who have studied most closely, know that they have not acquired too much; whilst those who have not studied at all have to depend on the skill of others, and, like all similar dependents, become more or less the dupes of those they employ.

523. That which is capable of increase or diminution is called *magnitude* or *quantity*. Hence the different kinds of magnitude must be many. Mathematics, generally speaking, is the *science of quantity*, or that which investigates the means of measuring quantity. Now we cannot measure or determine any quantity except by pointing out its relation to some other known quantity, so that the determination or the measure of magnitudes of all kinds is the making any one known magnitude of the same species the *measure* or *unit* for determining the proportion of the proposed magnitude to this known measure. This proportion being always expressed by numbers, a number is but the proportion of one magnitude to another, arbitrarily assumed as the unit. Hence all magnitudes may be expressed by numbers, and the foundation of all mathematical science must be laid in a study of the science of numbers, and in an examination of the different methods of calculation involved in it. In Algebra, or analysis numbers, which represent quantities, are alone considered, without respect to the different kinds of quantity. The latter are the subject of other branches of mathematics. Arithmetic is the *science of numbers properly so called*, extending only to certain methods of calculation which occur in common practice. Algebra comprehends all the cases that can exist in the calculation of numbers.

SIGNS + AND −.

524. (1.) When one number is to be added to another, the sign + (*plus*) is used, and is placed before the second number. Thus, $5+3$ denotes that 3 is to be added to the number 5, the sum whereof every body knows to be 8. The same sign may be used to connect several numbers, thus $7+9+12+81$ signifies that to the number 7 we must add 9, 12, and 81, which make 109. All this is evident, but in Algebra, in order to generalise numbers, they are represented by letters as a, b, c, d, &c.; thus $a+b+c+d$ signifies the sum of the numbers represented by those letters.

525. (2.) To subtract one number from another the sign − (*minus*) is used, which is placed before the number to be subtracted; thus $10-6$ signifies that the number 6 is to be taken from the number 10, so that the expression is equivalent to the number 4. So of several numbers; as, for instance, $62-6-15-31$ signifies that 6 is to be take from 62,

the remainder is 56; 15 taken from that remainder leaves 41; lastly, take from this 31, and the remainder is 10, which is the value of the expression. We might, however, have taken the sum of the numbers 6, 15, and 31 or 52 at once from 62, and the remainder is 10, as before.

526. It is easy, therefore, to determine the value of expressions in which both the signs + plus and − minus are found; for example, $16-4-7+3-1$ is the same as 7. For we have only to collect the numbers with the sign + before them, and subtract from their sum those that have the sign −. Thus, the sum of 16 and 3 is 19; that of 4, 7, and 1 is 12; and 12 being taken from 19 the remainder is 7. It must be remembered that in the expression the sign + is supposed to stand before the number 16; and that the above expression might have been arranged thus: $16+3-4-7-1$, or $3-1-4-7+16$, or $3+16-1-7-4$. If, instead of numbers, we use letters, no more difficulty occurs; for example —

$$a-b-c+d-e$$

signifies that certain numbers are expressed by a and d, and that from them or their sum the numbers expressed by the letters b, c, and e, having the sign − before them, are to be subtracted. Hence attention is necessary to the sign prefixed to each number, for in algebra simple quantities are numbers considered with respect to the signs which affect them. Those quantities before which the sign + is found are called *positive quantities*, and those affected by the sign − are called *negative quantities*. To illustrate this, let us suppose a man having 1000*l.*, but owing 400*l.*, it is evident his real wealth is only 1000*l.* − 400*l.*, 600*l.* Thus, negative numbers may be considered as debts, because positive numbers represent real possessions, and we may, indeed, say that negative numbers are less than nothing. For, take a man having nothing, and at the same time owing 100 pounds, it is clear he has 100 pounds less than nothing; for, if he had a present of 100 pounds made him to pay his debts, though he would be richer than before, he would still be at the point nothing. So, therefore, as positive numbers are clearly greater than nothing, negative numbers are less than nothing. Now, positive numbers are obtained by adding 1 to 0, that is, to nothing, and by thus increasing them from unity. This is the origin of the series called *natural numbers*, of which the following are the leading terms of the series: $0+1+2+3+4+5+6+7+8+9+10$, and so on to infinity. But if, instead of adding, we perpetually subtract unity, we have a series of negative numbers, thus: $0-1-2-3-4-5-6-7-8-9-10$, &c. to infinity. These numbers, whether positive or negative, are called whole numbers or *integers*, either greater or less than nothing. They are so called to distinguish them from fractions and other kinds of numbers, which will be hereafter noticed. Thus, between 2 greater by a unit than 1, it is easy to conceive an infinity of numbers greater than 1, yet all less than 2; for imagine a line of 2 ft. long and another 1, it is evident that an infinite number of lines may be drawn, all longer than 1 ft., but not so long as 2 ft. That a precise idea may be formed of negative quantities, the reader must keep in mind that all such expressions as $+1-1$, $+2-2$, $+3-3$, &c. are equal to 0, and that $+2-5$ is equal to -3. For, if a person has 2 pounds and owes 5, he has not only nothing, but still owes 3 pounds; and the same observation holds true with respect to letters, which represent numbers, thus $+a-a$ is 0. But, if the value of $+a-b$ is wanted, two cases are to be considered: first, if a is greater than b it must be subtracted from a, and the remainder, with the sign + placed or understood before it, is the value sought; secondly, if a is less than b, a is to be subtracted from b, and the remainder must have the negative sign placed before it.

MULTIPLICATION OF SIMPLE QUANTITIES.

527. (3.) In the multiplication of simple quantities, where two or more equal quantities are added together, the expression of their sum may be abridged thus: —

$a+a$ is the same as $2\times a$,
$a+a+a$ . . . . . . $3\times a$,
$a+a+a+a$ . . . . $4\times a$, and so on;

where × is the sign of multiplication.

Thus we obtain an idea of multiplication; for in the above, it must be observed that $2\times a$ signifies 2 times a, $3\times a$ signifies three times a, $4\times a$ four times a. But this form is abbreviated by simply putting the number before the letter; thus, a multiplied by 3 is expressed $3a$: b multiplied by 5 is $5b$: c taken but once, or $1c$, is no more than c. Hence the multiplication of such products by other numbers is simple enough, for

2 times $3a$ is equal to $6a$
3 times $4b$ . . . . . . $12b$
7 times $7x$ . . . . . . $49x$

and these products may be further multiplied at pleasure.

528. Suppose both the numbers be represented by letters, we have only to place one before the other, and the process is complete; thus a multiplied by b is ab; and if again we multiply this product by pq, the result is $abpq$. The order of the letters is no consequence; for suppose a to represent 5, and b 6, then ba or ab equally represent 6×5 and 5×6, which give the same product. But in the use of common numbers this cannot be done; for were we to write 34 for 3 times 4, we should have 34 instead of 12. If the sign × is omitted, it is usual to place a point between the figures; thus, $1 . 2 . 3 . 4 . 5$ is 120, as is $1 \times 2 \times 3 \times 4 \times 5$. Hence, if we meet with the expression $2 . 3 . 4\ xyz$, it means that 2 is to be multiplied by 3, and the product by 4; and that product first by x, then by y, and lastly by z, hence this may be abridged into $24\ xyz$.

529. The result arising from the multiplication of two numbers is called a *product*, and the numbers or letters are called *factors*.

530. In the case of positive numbers being multiplied into each other, no doubt can remain of the products being positive, for $+a \times +b$ must necessarily give ab. But the multiplication of $+a$ by $-b$, or of $-a$ by $-b$, requires examination. Suppose $-a$ multiplied by 3; now, as $-a$ may be taken as a debt, if multiplied by 3 it is three times greater; hence the product must be $-3a$. And if that be multiplied by $+b$, it is evident the debt is still increased by the action of b upon it; it becomes $-ba$, or, which is the same thing, $-ab$. On this account it is evident that if a positive be multiplied by a negative quantity, the product becomes worse, or, if the expression might be allowed, more negative. From this follows the rule, that + by + is always *plus*, and that + by −, on the contrary, gives a *minus* quantity. But the case in which − is multiplied by minus, that of $-a$ by $-b$, requires consideration. There can be no doubt that the product is ab; the sign, however, to be prefixed to it is at first sight not so clear. Now we have seen that it cannot be −, for $-a$ multiplied by $+b$ gives $-ab$, and $-a$ by $-b$, cannot produce the same result as $-a$ by $+b$; hence it must produce a contrary result, that is $+ab$, and hence results the following rule: − multiplied by − produces + just in the same manner as + by +. This is more briefly expressed in the following terms, *Like signs multiplied together give* +, *unlike or contrary signs give* −, whereof take as an example the multiplication of the following numbers, $+a$, $-b$, $-c$, $+d$. First $+a$ multiplied by $-b$ makes $-ab$, this by c gives $+abc$, and this last by $+d$ gives $+abcd$.

531. It remains only to show how to multiply numbers that are themselves products. Now, to multiply the number ab by the number cd, it is manifest, from what has been said, that the product is $abcd$, and that it is obtained by first multiplying ab by c, and the product by d. Or, if we had to multiply 36 by 12, 12 being equal to 3 times 4, we should first multiply 36 by 3, and the product 108 by 4, in order to have the whole product of the multiplication of 12 by 36, or 432. But, if we have to multiply $5ab$ by $3xy$, we may write $3xy \times 5ab$; but, as the order of the numbers is indifferent, it is better, and is the custom, to place the common numbers before the letters, and to express the product thus: $5 \times 3abxy$, or $15abxy$; 5 times 3 being 15, so $6abc$ by $7xy$ gives $42abcxy$.

WHOLE NUMBERS IN RESPECT TO THEIR FACTORS.

532. A product, as we have seen, is generated by the multiplication of two or more numbers. These are called *factors*. Thus, $abcd$ are the factors of the product $abcd$. All whole numbers cannot result from such a multiplication: those which are in that predicament have not any factors. Thus, 4 is produced by 2×2, 6 by 2×3, 8 by $2 \times 2 \times 2$, 27 by $3 \times 3 \times 3$, &c. But the numbers 2, 3, 5, 7, 11, 13, 17, &c. cannot be represented by factors, unless, for the purpose, we make use of unity, and represent, for instance, 2 by 1×2. Now, as numbers which are multiplied by 1 remain the same, unity cannot be reckoned as a factor. Hence, all numbers, such as 2, 3, 5, 7, &c., which cannot be represented by factors, are called *simple*, or *prime numbers*, whereas others, as 4, 6, 8, 9, 10, 12, 14, 15, 16, 18, &c., which can be represented by factors, are called *compound numbers*: *simple or prime numbers* consequently deserve particular attention, inasmuch as they do not result from the multiplication of two or more numbers; and it is worthy of observation, that in writing these numbers in succession as they follow each other, thus, 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, &c., no regular order is perceptible, their increments being sometimes greater, sometimes less, and, as yet, no law which they follow has been discovered.

533. All *compound numbers* which may be represented by factors have prime numbers for their factors; for if a factor is found which is not a prime number, it may be decomposed and represented by two or more prime numbers. Thus, if we represent the number 30 by 5×6, 6, not being a prime number, might have been represented by 2×3, that is $5 \times 2 \times 3$, in which the numbers are all prime; numbers equally represent 30.

There is much difference between compound numbers, which may be resolved into prime numbers; some have only two factors, others three, and others still more. Thus we have seen that

4 is the same as. . . . 2×2
8 . . . . $2 \times 2 \times 2$
10 . . . . 2×5
14 . . . . 2×7
16 . . . . $2 \times 2 \times 2 \times 2$
6 is the same as. . 2×3
9 . . . . 3×3
12 . . . . $2 \times 3 \times 2$
15 . . . . 3×5
and so on.

The analysis, therefore, of any number, or the resolution of it into simple factors, is easily accomplished. Take, for instance, the number 360. First, it may be represented by 2×180. Then 180 is equal to 2×90, and

$$\left.\begin{array}{r} 90 \\ 45 \\ 15 \end{array}\right\} \text{is the same as} \left\{\begin{array}{l} 2 \times 45 \\ 3 \times 15 \\ 3 \times 5 \end{array}\right.$$

So that the number 360 may be represented by these simple factors, $2 \times 2 \times 2 \times 3 \times 3 \times 5$, since these numbers multiplied together produce 360. This shows that prime numbers cannot be divided by other numbers, and that the simple factors of compound numbers are most conveniently found by seeking the prime numbers, by which compound numbers are divisible.

DIVISION OF SIMPLE QUANTITIES.

534. The separation of a number into two or more equal parts is called *division*, which enables us to determine the magnitude of one of those parts. For instance, suppose we wish to separate 12 into three equal parts, we find, by division, that each of those parts is equal to 4. The number to be divided is called the *dividend*, the number of equal parts into which it is to be separated is called the *divisor*, and the magnitude of one of the parts determined by the division is the *quotient:* thus, in the example, —

12 is the dividend,
3 is the divisor,
4 is the quotient.

From this it is evident that if we divide the number 2 into two equal parts, one of those parts, or the quotient taken twice, is exactly the number proposed; and so, if a number is to be divided by 3, the quotient thrice taken must again give the same number. Hence follows the general rule that the *quotient multiplied by the divisor reproduces the dividend*. The dividend, indeed, may be considered a product, whereof one factor is the divisor and the other the quotient. For, if we have 40 to divide by 8, we have to find a product in which one of the factors is 8, and another factor which multiplied by it may give 40. Now 5×8 is a product which answers the hypothesis, and therefore 5 is the quotient of 40 divided by 8.

535. Generally, a number ab divided by a gives a quotient b, because a multiplied by b gives the dividend ab. So, if we have to divide ab by b, the quotient must be a. In short, the whole operation of division consists in representing the dividend by two factors whereof one is equal to the divisor and the other to the quotient; thus the dividend abc divided by a gives bc, for a multiplied by bc produces abc; and, similarly, abc divided by b gives ac, and abc divided by ac gives b. So $16xy$ divided by $4x$ gives $4y$, inasmuch as 4 times x multiplied by 4 times y produces $16xy$; but had $16xy$ been divided by 16, the quotient must have been xy.

536. A number a is the same as $1a$; hence, if a or $1a$ is to be divided by 1 the quotient must be the same number a; but if the same number a or $1a$ be divided by a, the quotient must be 1.

537. The dividend cannot always be represented as the product of two factors, whereof one is equal to the divisor; in which case other expressions must be had recourse to. Thus, in dividing 19 by 6, it is obvious that the number 6 is not a factor of 19, for 6×3 is but 18, and therefore too small, and 6×4 produces 24, which is too large; from which it is evident that the quotient is greater than 3 and less than 4. To determine this exactly, a species of numbers called *fractions* is used, whereof we shall hereafter treat. But previous to that, let us investigate the number which nearest approaches to the true quotient, with attention to the *remainder* left, thus: —

$$\begin{array}{l} 6)\,19\,(3 \\ 18 \\ \overline{1} \end{array}$$

where the dividend is 19, the divisor 6, the quotient 3, leaving a remainder of 1. Now, if we multiply the divisor 6 by the quotient 3, and thereto add the remainder, we have the dividend, and this proves the correctness of the division; for 3 multiplied by 6 produces 18, to which, if the remainder 1 be added, we have 19, the dividend.

538. Here it must be observed, in respect of the signs + and −, that $+ab$ divided by $+a$ must be $+b$; for it is evident that $+a$ multiplied by $+b$ gives $+ab$. But, if $+ab$ be divided by $-a$, the quotient must be $-b$, because $-a$ multiplied by $-b$ produces $+ab$. Suppose the dividend $-ab$ divided by $+a$, the quotient must be $-b$, because $-b$ multiplied by $+a$ makes $-ab$. Lastly, the dividend $-ab$ divided by $-a$ must have for its quotient $+b$, for the dividend $-ab$ is produced by $-a$ by $+b$.

539. In division, therefore, the same rules hold respecting the signs + and − as in multiplication; namely, —

+ by + give + and + by − give −,
− by + give − and − by − give +,

or, as it is usually expressed, *like* signs give *plus*, and *unlike* signs give *minus*.

Thus, dividing $21xy$ by $-3y$, the quotient is $-7x$; and

$-40pq$ divided by $+4p$ gives $-10q$;

and $-72xyz$ divided by $-8y$ gives $+9xz$;

for $-8y$ multiplied by $+9xz$ makes $-9+8xyz$, or $-72xyz$.

THE PROPERTIES OF INTEGERS AS RESPECTS THEIR DIVISORS.

540. Some numbers are, it has been seen, divisible by certain divisors, others are not so. Let us look to this difference between them. Take the divisors 2, 3, 4, 5, 6, 7, 8, 9, 10, &c.

541. Now in the divisor 2 the numbers it will exactly divide are manifestly 2, 4, 6, 8, 10, 12, &c., in which the series increases uniformly by 2, and they are called *even numbers*. But in the numbers 1, 3, 5, 7, 9, 11, 13, 15, &c. there is an uniformly less or greater number by unity than in the former not divisible by 2 without a remainder 1: these are called *odd numbers*.

542. The general expression $2a$ includes all the even numbers, for they are obtained by successively substituting the integers 1, 2, 3, 4, 5, 6, 7, &c.; and for this reason the odd numbers are comprehended in the expression $2a+1$, because $2a+1$ is greater by unity than the even number $2a$.

543. In the second place, suppose 3 to be the divisor, the numbers it will exactly divide are 3, 6, 9, 12, 15, 18, 21, &c., which numbers are comprehended in the expression $3a$, for dividing $3a$ by 3 the quotient is a without a remainder. All other numbers that we would divide by 3 will give 1 or 2 for a remainder; and hence they are of two kinds: first, those leaving the remainder 1 after the division, which are 1, 4, 7, 10, 13, 16, &c., and are contained in the expression $3a+1$; second, those in which 2 is the remainder, and these are 2, 5, 8, 11, 14, 17, 20, and these may be expressed $3a+2$; so that all these numbers may be expressed by $3a$, $3a+1$, or by $3a+2$.

544. Suppose 4 to be the divisor, it will divide the following numbers, 4, 8, 12, 16, 20, 24, &c., which increase uniformly by 4, and are comprehended in the expression $4a$. All other numbers not divisible by 4 may leave the remainder 1, or be greater by 1 than the former, as 1, 5, 9, 13, 17, 21, &c., and may be comprehended in the expression $4a+1$: or they may give 2 as a remainder, as 2, 6, 10, 14, 18, 22, &c., and be expressed by $4a+2$; or, lastly, they may give the remainder 3, and as 3, 7, 11, 15, 19, 23, &c., and be represented by the expression $4a+3$. All possible integer numbers are hence contained in one or other of the four expressions $4a$, $4a+1$, $4a+2$, $4a+3$.

545. If the divisor is 5 it is nearly the same, for all numbers divisible by it are comprehended in the expression $5a$, and if not divisible by 5 they may be reduced to one of these expressions, $5a+1$, $5a+2$, $5a+3$, $5a+4$, and so we may go on to the greatest divisors.

546. It is necessary to keep in mind, as we have noticed in a previous passage on the resolution of numbers into their simple factors, that all numbers among whose factors are found 2 or 3, or 4, or 5 or 7, or any other number, are divisible by those numbers. For example, 48 being equal to $2 \times 2 \times 3 \times 4$, it is clear that 48 is divisible by 2 and by 3 and by 4.

547. As the general expression $abcd$ is not only divisible by a and b, and c and d, but also by

ab, ac, ad, bc, bd, cd;
and by abc, abd, acd, bcd;
and, lastly, by $abcd$, which is its own value:

it is clear that 48, or $2 \times 2 \times 3 \times 4$, may be divided not only by those simple numbers, but by those composed of two of them, that is, by 4, 6, 8, 12; and also by those composed of three of them, that is, by 12, 16, 24; and, lastly, by 48 itself. From this it follows, that when a number has been represented by its factor it is easy to find all the numbers by which it is divisible.

548. It is necessary to observe, that every number is divisible by 1 and by itself, so that there is no number that has not at least two factors or divisors, the number itself and unity; but if a number have no other than these two it belongs to the class of numbers called prime numbers. With the exception of those, all numbers have other divisor besides unity and themselves, as may be seen from the subjoined table, wherein all its divisors are placed under each number, and the prime numbers marked with a P.

Numbers - - -	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Divisors - - -	1	1 2	1 3	1 2 4	1 5	1 2 3 6	1 7	1 2 4 8	1 3 9	1 2 5 10	1 11	1 2 3 4 6 12	1 13	1 2 7 14	1 3 5 15	1 2 4 8 16	1 17	1 2 3 6 9 18	1 19	1 2 4 5 10 20
Number of divisors -	1	2	2	3	2	4	2	4	3	4	2	6	2	4	4	5	2	6	2	6
	P	P	P		P		P				P		P				P		P	

We must here observe, that 0, or nothing, may be considered a number having the property of being divisible by all possible numbers, because by whatever number $a0$ is divided, the quotient must be 0; for the multiplication of any number by nothing produces nothing, hence $0a$ is 0.

FRACTIONS.

549. When a number is said not to be divisible by another number, it only means that the quotient cannot be expressed by an integer number. For if we imagine a line of 7 feet in length, it is impossible to doubt that it may be divided into three equal parts, of the length of each whereof a notion may be formed. But as the quotient of 7 divided by 3 is not an integer number, we are thus led to the consideration of a particular species of numbers called *fractions* or *broken numbers*. If we have to divide 7 by 3 the quotient may be conceived and expressed by $\frac{7}{3}$, placing the divisor under the dividend, and separating them by a stroke or line.

550. Generally, moreover, if the number a is to be divided by the number b, the quotient is $\frac{a}{b}$, and this form of expression is called a fraction. In all fractions the lower number is called the *denominator*, and that above the line the *numerator*. In the above fraction of $\frac{7}{3}$, which is read *seven thirds*, 7 is the numerator and 3 the denominator. In reading fractions we call $\frac{4}{5}$ four fifths, $\frac{7}{18}$ seven eighteenths, $\frac{15}{100}$ fifteen hundredths, and $\frac{1}{2}$ one half.

551. In order to become thoroughly acquainted with the nature of fractions it is proper to begin by considering the case of the numerator being equal to the denominator as $\frac{a}{a}$. Now as this is a representation of the quotient obtained by dividing a by a, it is evident it is once contained in it, that is, the quotient is exactly unity, hence $\frac{a}{a}$ is equal to 1; and for the same reason all the following fractions, $\frac{2}{2}$, $\frac{3}{3}$, $\frac{4}{4}$, $\frac{5}{5}$, $\frac{6}{6}$, $\frac{7}{7}$, &c., are equal to one another, each being equal to unity. It is evident, then, that fractions whose numerators are less than the denominators have a value less than unity, for if a number be divided by another which is greater, the result must necessarily be less than 1. Thus, if a line two feet long be cut into three parts, two of them will undoubtedly be shorter than a foot; it is evident, then, that $\frac{2}{3}$ is less than 1, for the same reason that the numerator 2 is less than the denominator 3.

552. But if, on the contrary, the numerator be greater than the denominator, the value of the fraction is greater than unity. Thus $\frac{4}{3}$ is greater than 1, for $\frac{4}{3}$ is equal to $\frac{3}{3}$ together with $\frac{1}{3}$. Now $\frac{3}{3}$ is exactly 1, consequently $\frac{4}{3}$ is equal to $1+\frac{1}{3}$, that is, to an integer and a third. So $\frac{6}{4}$ is equal to $1\frac{2}{4}$, or $1\frac{1}{2}$; $\frac{7}{4}$ is equal to $1\frac{3}{4}$; and $\frac{12}{5}$ is equal to $2\frac{2}{5}$. Generally, if we divide the upper member by the lower, and add to the quotient a fraction whose numerator expresses the remainder and the divisor the denominator, we shall in other terms represent the fraction. For example, in the fraction $\frac{48}{15}$ the quotient is 3 and the remainder 3, hence $\frac{48}{15}$ is the same as $3\frac{3}{15}$.

553. Fractions, then, whose numerators are greater than their denominators, consist of two numbers; one of which is an integer, and the other a fractional number, in which the numerator is less than the denominator; and when fractions contain one or more integers, they are called *improper fractions*, to distinguish them from fractions properly so called, in which the numerator is less than the denominator, whence they are less than unity, or than an integer. There is another way of considering fractions, which may illustrate the sub-

ject. Thus, in the fraction $\frac{5}{10}$ it is evident that it is five times greater than $\frac{1}{10}$. This last fraction expresses one of the 10 parts into which 1 may be divided, and that in taking five of those parts we have the value of the fraction $\frac{5}{10}$.

554. It is from this mode of considering a fraction that the terms *numerator* and *denominator* are derived; that is to say, the lower number expresses or *denotes* the number of parts into which the integer is divided, and is therefore called the *denominator*, the upper number, or that above the line *numbers* the quantity of those parts, and is thence called the *numerator*. It follows, then, that as the denominator is increased the smaller the parts become, as in $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{8}$, and so on; and it is evident that if the integer be divided into two parts, each of those parts is greater than if it had been divided into eight. In this division of the integer it is impossible to increase the denominator so that the fraction shall be reduced to nothing; for into whatever number of parts unity may be divided, however small they be, they still preserve some definite magnitude. Indeed, to whatever extent we continue the series of fractions just named, they will always represent a certain quantity. From this has arisen the expression that the denominator must be infinitely great, or *infinite*, to reduce the fraction to 0, or nothing, which in this case means nothing more than that it is impossible to reach the end of the series of the fractions in question. This idea is expressed by the use of the sign ∞, which indicates a number infinitely great, and we may therefore say that $\frac{1}{\infty}$ is really nothing, because a fraction can only be lessened to nothing when the denominator has been increased to infinity. This, moreover, leads us to another view of the matter, which is important. The fraction $\frac{1}{\infty}$, as we have seen, represents the quotient resulting from the division of 1 by ∞. Now, if 1 be divided by $\frac{1}{\infty}$ or 0, the divisor will be again ∞, and a new idea of affinity is thus obtained, arising from the division of 1 by 0; and thus we are justified in saying that 1 divided by 0 expresses ∞, or a number infinitely great. From this, moreover, we learn that a number infinitely great is susceptible of increase, for having seen that $\frac{1}{0}$ denotes a number infinitely great, $\frac{2}{0}$, the double of it, must be greater, and so on.

PROPERTIES OF FRACTIONS.

555. It has been seen that $\frac{2}{2}$, $\frac{3}{3}$, $\frac{4}{4}$, $\frac{5}{5}$, &c. are equal to 1, and thence equal to one another; the same equality obtains in the fractions $\frac{2}{1}$, $\frac{4}{2}$, $\frac{6}{3}$, $\frac{8}{4}$, &c., which, from what has been said, it is obvious are each equal to 2, and to one another, so the fractions $\frac{3}{1}$, $\frac{6}{2}$, $\frac{9}{3}$, $\frac{12}{4}$ are, from their common value, being 3 each, equal to one another. In the same way, a fraction may be represented in an infinity of ways by multiplying the numerator and denominator by the same number, be that number what it may; thus, $\frac{1}{2}$, $\frac{4}{8}$, $\frac{7}{14}$, $\frac{10}{20}$, $\frac{13}{26}$, &c. are equal, the common value being $\frac{1}{2}$. So, to give another example, $\frac{1}{7}$, $\frac{2}{14}$, $\frac{3}{21}$, $\frac{4}{28}$, $\frac{5}{35}$, are all equal to $\frac{1}{7}$. Hence, we arrive at the general conclusion that the fraction $\frac{a}{b}$, may be equally represented by the following expressions, each equal to $\frac{a}{b}$, viz. $\frac{a}{b}$, $\frac{2a}{2b}$, $\frac{3a}{3b}$, $\frac{4a}{4b}$, &c. That this is the case we may see by substituting a certain letter c for the fraction $\frac{a}{b}$, which letter we will consider as representing the quotient of a divided by b; recollecting, then, that the multiplication of the quotient c by the divisor b must give the dividend; for by the hypothesis, as c multiplied by b gives a, it is evident that c multiplied by $2b$ must give $2a$, that c multiplied by $3b$ will give $3a$; and that in general c multiplied by mb (m representing any given number) must give ma. The converse brings us to the division of a by b, in which, if we divide the product ma by mb one of the factors, the quotient is equal to c, the other factor. But ma divided by mb gives also the fraction $\frac{ma}{mb}$, which is therefore equal to c, which was the matter to be proved; for c was assumed as the value of the fraction $\frac{a}{b}$, and hence this fraction is equal to the fraction $\frac{ma}{mb}$, whatever the value of m.

556. The infinite forms in which fractions may be represented, so as to express the same value, has been before shown; and it is obvious, that of those forms, that which is given in the smallest numbers is more immediately understood. Thus the fraction $\frac{1}{4}$, or one quarter, is more easily comprehended than $\frac{4}{16}$, $\frac{5}{20}$, $\frac{6}{24}$, $\frac{7}{28}$, &c. It therefore becomes a matter of convenience to express a fraction in the least possible numbers, or in its least terms. This is a problem not difficult of resolution when we recollect that all fractions retain their value if the numerator and denominator are multiplied by the same number, from which we also learn that if they are divided by the same number their value is not altered. As an example in the general expression $\frac{ma}{mb}$, if both numerator and denominator be divided by the number m, we obtain the fraction $\frac{a}{b}$, which has before been seen to be equal to $\frac{ma}{mb}$.

557. From the above, then, it is evident that to reduce a fraction to its least terms, we have only to find a number which will divide the numerator and denominator, and this number is called a *common divisor*, which if we can find, the fraction may be reduced to a lower form; but if we cannot find such a number, and unity is the only common divisor that can be found, the fraction is already in its simplest form. Thus, taking the fraction $\frac{96}{360}$, we may immediately perceive that 2 will divide both the terms, whereof the result is $\frac{48}{180}$; this result is again divisible by 2, by which the fraction is reduced to $\frac{24}{90}$, in which we again find 2 as a common divisor, and the result of that is $\frac{12}{45}$. In this we may perceive that, as 2 will no longer divide the terms, another number must be sought, and by trial that number will be seen to be 3, by using which we obtain the fraction $\frac{4}{15}$, the simplest expression to which it can be reduced, for 1 is the only common divisor of the numbers 4 and 15, and division by unity will not reduce those numbers. This property of the invariable value of fractions leads to the conclusion that in the addition and subtraction of them, the operations are performed with difficulty, unless they are reduced to expressions wherein the denominators are equal. And here it will be useful to observe that all integers are capable of being represented by fractions; for it is manifest that 9 and $\frac{9}{1}$ are the same, 9 divided by 1 giving a quotient of 9; which last number may also be equally represented by $\frac{18}{2}$, $\frac{36}{4}$, $\frac{72}{8}$, $\frac{144}{16}$, &c. &c.

ADDITION AND SUBTRACTION OF FRACTIONS.

558. When the denominators of fractions are equal they are easily added to and subtracted from one another: thus, $\frac{3}{8}+\frac{5}{8}$ is equal to $\frac{8}{8}$ or 1, and $\frac{5}{8}-\frac{3}{8}$ is equal to $\frac{2}{8}$ or $\frac{1}{4}$. In this case, either for addition or subtraction, it is only necessary to change the numerators and place the common denominator under the result, thus: —

$$\frac{8}{14} - \frac{2}{14} + \frac{5}{14} - \frac{4}{14} = \frac{7}{14} \text{ or } \frac{1}{2}$$
$$\frac{9}{13} - \frac{4}{13} - \frac{1}{13} + \frac{2}{13} = \frac{6}{13}$$
$$\frac{1}{7} + \frac{6}{7} = \frac{7}{7} \text{ or } 1$$
$$\frac{3}{8} - \frac{4}{8} + \frac{1}{8} = \frac{0}{8} \text{ or nothing.}$$

If fractions have not the same denominator, they must, for the purpose in question, be changed into others that are in that condition. For an example, let us take the fractions $\frac{1}{2}$ and $\frac{1}{3}$; it is evident that $\frac{1}{2}$ is the same as $\frac{3}{6}$, and that $\frac{1}{3}$ is equivalent to $\frac{2}{6}$; the fractions for adding together therefore become $\frac{3}{6}+\frac{2}{6}$, whose sum is $\frac{5}{6}$. If the latter is to be subtracted from the former, or, in other words, to be united by the sign −, as $\frac{1}{2}-\frac{1}{3}$, we shall have $\frac{3}{6}-\frac{2}{6}$, or $\frac{1}{6}$.

559. It often becomes necessary to reduce a number of fractions to a common denominator: thus, suppose we have the fractions $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{4}$, $\frac{4}{5}$, $\frac{5}{6}$. We have here only to find a number divisible by all the denominators of those fractions. In the above case, that number will, by trial, be seen to be 60, which therefore will be the common denominator. Substituting this, we shall have $\frac{30}{60}$ instead of $\frac{1}{2}$; $\frac{40}{60}$ instead of $\frac{2}{3}$; $\frac{45}{60}$ instead of $\frac{3}{4}$; $\frac{48}{60}$ instead of $\frac{4}{5}$; and $\frac{50}{60}$ instead of $\frac{5}{6}$. The addition of all these fractions thus becomes simple enough, for we have only to add the numerators together, and place under that sum the common denominator, that is to say, we shall have $\frac{213}{60}$, which is equal to $3\frac{33}{60}$ or $3\frac{11}{20}$. Thus, all that is necessary is to change two fractions whose denominators are unequal into two others whose denominators are equal. For the performance of this generally, if $\frac{a}{b}$ and $\frac{c}{d}$ be the fractions, first multiply both the terms of the first fraction by d, and we shall have $\frac{ad}{bd}$ equal to $\frac{a}{b}$; then multiply both the terms of the second fractions by b, and we have its equivalent value in $\frac{bc}{bd}$, whereby also the two denominators are become equal. The sum of these fractions is now readily obtained, being $\frac{ad+bc}{bd}$, and their difference is evidently $\frac{ad-bc}{bd}$. Suppose the fractions $\frac{5}{9}$ and $\frac{7}{8}$ proposed, we have in their stead $\frac{40}{72}$ and $\frac{63}{72}$, whereof the sum is $\frac{103}{72}$, and the difference $\frac{23}{72}$. It is by the method just mentioned that we are enabled to ascertain which is the greater and which the less; thus, in the two fractions $\frac{3}{5}$ and $\frac{4}{9}$, it is evident that the last is smaller than the first, for, reduced to the same denominator, the first is $\frac{27}{45}$, and the second $\frac{20}{45}$, whence it is evident that $\frac{4}{9}$ is less than $\frac{3}{5}$ by $\frac{7}{45}$.

560. To subtract a fraction from an integer, it is only necessary to change one of its units into a fraction having the same denominator as that which is to be subtracted: thus to subtract $\frac{3}{5}$ from 1 we write $\frac{5}{5}$ instead of 1, from which if $\frac{3}{5}$ be taken $\frac{2}{5}$ remain. Again, suppose $\frac{3}{4}$ is to be subtracted from 2, we may either write $\frac{8}{4}$ or $1\frac{4}{4}$, from which $\frac{3}{4}$ subtracted leave $\frac{5}{4}$ or $1\frac{1}{4}$. It is only necessary to divide the numerator by the denominator, to see how many integers it contains. We have nearly the same operation to perform in adding numbers composed of integers and fractions; thus, let it be proposed to add $5\frac{1}{2}$ to $3\frac{1}{3}$, then taking $\frac{1}{2}$ and $\frac{1}{3}$, or, which is the same, $\frac{3}{6}$ and $\frac{2}{6}$, their sum is $\frac{5}{6}$; the sum total, therefore, will be $8\frac{5}{6}$.

MULTIPLICATION AND DIVISION OF FRACTIONS.

561. For the multiplication of a fraction by an integer, or whole number, the rule is to multiply the numerator only by the given number, the denominator remaining unchanged: thus —

2 times or twice $\frac{1}{2}$ makes $\frac{2}{2}$ or 1 integer,
2 times or twice $\frac{1}{3}$ makes $\frac{2}{3}$,
3 times or thrice $\frac{1}{6}$ makes $\frac{3}{6}$ or $\frac{1}{2}$,
4 times $\frac{5}{12}$ makes $\frac{20}{12}$ or $1\frac{8}{12}$ or $1\frac{2}{3}$.

But when it can be done, it is preferable to divide the denominator by the integer, inasmuch as the operation is shortened by it; for example, in multiplying $\frac{8}{9}$ by 3, by the rule above given, we have $\frac{24}{9}$, which is reduced then to $\frac{8}{3}$, and, lastly, to $2\frac{2}{3}$. But if the numerator remain and the denominator is divided by the integer, we have at once $\frac{8}{3}$ or $2\frac{2}{3}$ for the product sought. Likewise $\frac{14}{20}$ multiplied by 5 gives $\frac{14}{4}$ or $3\frac{2}{4}$, that is $3\frac{1}{2}$.

562. Generally, then, the product of the multiplication of a fraction $\frac{a}{b}$ by c is $\frac{ac}{b}$, and it is to be observed that when the integer is exactly equal to the denominator, the product must be equal to the numerator. So that —

$\frac{1}{2}$ taken twice gives 1,
$\frac{2}{3}$ taken thrice gives 2,
$\frac{3}{4}$ taken 4 times gives 3.

and, generally, if the fraction $\frac{a}{b}$ be multiplied by the number b, the product, as has already been seen, must be b, for as $\frac{a}{b}$ represents a quotient resulting from the division of the dividend a by the divisor b, and since we have seen that the quotient multiplied by the divisor will give the dividend, it is evident that $\frac{a}{b}$ multiplied by b must produce a. We are next to consider how a fraction can be divided by an integer before proceeding to the multiplication of fractions by fractions. It is evident, if I have to divide the fraction $\frac{3}{4}$ by 3, the result is $\frac{1}{4}$, and that the quotient of $\frac{8}{9}$ divided by 4 is $\frac{2}{9}$: the rule is therefore to divide the numerator by the integer, and leave the denominator unchanged. Thus —

$\frac{14}{23}$ divided by 2 gives $\frac{7}{23}$,
$\frac{14}{23}$ divided by 7 gives $\frac{2}{23}$, &c. &c.

563. The rule is easily applied if the numerator be divisible by the number proposed; as this is not always the case, it is to be observed that a fraction may be transformed into an infinite number of similar expressions, in some of which the numerator might be divided by the given integer. Thus, for example, to divide $\frac{3}{4}$ by 2, we may change the fraction into $\frac{6}{8}$, in which the numerator may be divided by 2, and the quotient is therefore $\frac{3}{8}$.

564. In general, to divide the fraction $\frac{a}{b}$ by c, it is changed into $\frac{ac}{bc}$, and then dividing the numerator ac by c, write $\frac{a}{bc}$ for the quotient sought.

565. Hence, when a fraction $\frac{a}{b}$ is to be divided by an integer c, it is necessary merely to multiply the denominator by that number, leaving the numerator as it is. Thus, $\frac{5}{6}$ divided by 3 gives $\frac{5}{18}$, and $\frac{7}{8}$ divided by 6 gives $\frac{7}{48}$. When, however, the numerator is divisible by the integer, the operation is still simpler. Thus, $\frac{9}{16}$ divided by 3 would give according to the first given rule $\frac{9}{48}$, but by this last rule we at once obtain $\frac{3}{16}$, an expression equivalent to, but more simple than, $\frac{9}{48}$.

566. We now perceive, then, in what way one fraction $\frac{a}{b}$ may be multiplied by another $\frac{c}{d}$. Here $\frac{c}{d}$ means that c is to be divided by d, and on this principle we must first multiply $\frac{a}{b}$ by c, the result whereof is $\frac{ac}{b}$, after which we divide by d, which gives $\frac{ac}{bd}$.

From this arises the rule for multiplying fractions, which is, to multiply the numerators and denominators separately. Thus —

$\frac{1}{4}$ multiplied by $\frac{1}{6}$ gives the product $\frac{1}{24}$,
$\frac{3}{8}$ multiplied by $\frac{5}{12}$ produces $\frac{15}{96}$,
$\frac{1}{2}$ multiplied by $\frac{7}{10}$ produces $\frac{7}{20}$, &c. &c.

567. We are now to see how one fraction may be divided by another. And, first, it is to be observed, that if the two fractions have similar denominators, the division is performed only with respect to the numerators, for it is manifest that $\frac{3}{12}$ are as many times contained in $\frac{9}{12}$ as 3 in 9, that is, three times; and in the same manner in order to divide $\frac{7}{10}$ by $\frac{9}{10}$, we have only to divide 7 by 9 which is $\frac{7}{9}$. So we shall have $\frac{6}{20}$ in $\frac{18}{20}$ 3 times, $\frac{7}{100}$ in $\frac{49}{100}$ 7 times.

568. If the denominators of the fractions are not equal, they must, by the method before given, be reduced to a common denominator. Thus, if the fraction $\frac{a}{b}$ is to be divided by $\frac{c}{d}$, we have $\frac{ad}{bd}$ to be divided by $\frac{bc}{db}$; whence it becomes evident that the quotient will be represented simply by the division of *ad* by *bc* or $\frac{ad}{bc}$. Hence the following rule: multiply the numerator of the dividend by the denominator of the divisor, and the denominator of the dividend by the numeartor of the divisor, the first product will be the numerator of the quotient and the second its denominator.

569. If this rule be applied to the division of $\frac{3}{4}$ by $\frac{2}{3}$ we have $\frac{9}{8}$ or $1\frac{1}{8}$, and $\frac{25}{48}$ by $\frac{5}{8}$ gives $\frac{200}{240}$ or $\frac{5}{6}$.

570. There is a rule which operates the same results, and is more easily recollected; it is, to invert the fraction which is the divisor, that is, place the denominator for the numerator and the numerator for the denominator; then multiply the numerators together for a new numerator, and the denominators for a new denominator, and the product will be the quotient sought. Thus, $\frac{1}{2}$ divided by $\frac{2}{3}$ is the same as $\frac{1}{2}$ multiplied by $\frac{3}{2}$, which make $\frac{3}{4}$. Also $\frac{5}{8}$ divided by $\frac{3}{7}$ is the same as $\frac{5}{8}$ multiplied by $\frac{7}{3}$, which is $\frac{35}{24}$; that is, in general terms, to divide by the fraction $\frac{1}{2}$ is the same as to multiply by $\frac{2}{1}$ or 2, that division by $\frac{1}{3}$ is the same as multiplication by $\frac{3}{1}$ or by 3.

571. Thus, the number 100 divided by $\frac{1}{2}$ is 200, and 1000 divided by $\frac{1}{3}$ will give 3000. So also if 1 be divided by $\frac{1}{1000}$ the quotient would be 1000; and 1 divided by $\frac{1}{100000}$ gives 100,000. This view is useful in enabling us to conceive that, when any number is divided by 0, the result must be a number infinitely great; for the division of 1 by the small fraction $\frac{1}{1000000000}$ gives for a quotient 1,000,000,000.

572. As every number, when divided by itself, produces unity, a fraction divided by itself must also give 1 for a quotient. For to divide $\frac{3}{4}$ by $\frac{3}{4}$, we must, by the rule, multiply $\frac{3}{4}$ by $\frac{4}{3}$, by which we obtain $\frac{12}{12}$, or 1; and if it be required to divide $\frac{a}{b}$ by $\frac{a}{b}$, we multiply $\frac{a}{b}$ by $\frac{b}{a}$; now the product $\frac{ab}{ab}$ is equal to 1.

573. There remains to explain an expression in frequent use, — such, for instance, as the half of $\frac{3}{10}$: this signifies that we must multiply $\frac{3}{10}$ by $\frac{1}{2}$, which is $\frac{3}{20}$. So, if it be required to know the value of $\frac{1}{10}$ of $\frac{7}{8}$, they are to be multiplied together, which produces $\frac{7}{80}$; and $\frac{3}{4}$ of $\frac{9}{16}$ is the same as $\frac{9}{16}$ multiplied by $\frac{3}{4}$, which produces $\frac{27}{64}$.

574. We have, in a previous section, laid down for integers the signs of + and −, and the same rule holds with regard to fractions. Thus $+\frac{1}{2}$ multiplied by $-\frac{1}{3}$ makes $-\frac{1}{6}$; and $-\frac{3}{4}$ multiplied by $-\frac{4}{5}$ gives $+\frac{12}{20}$. Further, $-\frac{3}{4}$ divided by $+\frac{2}{3}$ makes $-\frac{9}{8}$, or $-1\frac{1}{8}$; and $-\frac{7}{8}$ divided by $-\frac{1}{4}$ makes $+\frac{28}{8}$, or $3\frac{4}{8}$, that is, $3\frac{1}{2}$.

SQUARE NUMBERS.

575. If a number be multiplied by itself, the product is called *a square*, in relation to which the number itself is called *a square root*. Thus, if we multiply 12 by 12, the product 144 is a square whose root is 12. The origin of this term is borrowed from geometry, by which we learn that the contents of a square are found by multiplying its side by itself.

576. Square numbers, therefore, are found by multiplying the root by itself. Thus, 1 is the square of 1; since 1 multiplied by 1 makes 1. So 25 is the square of 5, and 64 the square of 8. 7, also, is the root of 49, and 9 is the root of 81. Beginning with the squares of natural numbers, we subjoin a small table, in the first line whereof the roots or numbers are ranged, and on the second their squares.

Numbers . .	1	2	3	5	6	7	8	9	10	11	12	13
Squares . . .	1	4	9	25	36	49	64	81	100	121	144	169

577. A singular property will be immediately perceived in this table, which is, that in the series of square numbers, if the preceding one be subtracted from that following, the remainders always increase by ·2, forming the following series —

3, 5, 7, 9, 11, 13, 15, 17, 19, 21, &c.,

which is that of the odd numbers.

578. The squares of fractions are found in the same manner as those of whole numbers, that is, by multiplying any given fraction by itself; thus the square of $\frac{1}{2}$ is $\frac{1}{4}$,

$$\text{The square of} \left\{ \begin{matrix} \frac{1}{4} \\ \frac{3}{8} \\ \frac{4}{9} \\ \frac{5}{12} \end{matrix} \right\} \text{is} \left\{ \begin{matrix} \frac{1}{16} \\ \frac{9}{64} \\ \frac{16}{81} \\ \frac{25}{144} \end{matrix} \right.$$

Hence we have only to divide the square of the numerator by that of the denominator, and the fraction expressing that division is the square of the given fraction. Thus $\frac{49}{64}$ is the square of $\frac{7}{8}$, and, reciprocally, $\frac{7}{8}$ is the root of $\frac{49}{64}$.

579. If the square of a mixed number, or one that is composed of an integer and a fraction, be sought, no more is necessary than to reduce it to a single fraction, and then take the square of that fraction. Thus, to find the square of $2\frac{1}{4}$, it must first be expressed by the fraction $\frac{9}{4}$; and, taking its square, we have $\frac{81}{16}$, or $5\frac{1}{16}$ for the value of the square of $2\frac{1}{4}$. And so of any similar numbers. The squares of the numbers between 3 and 4, supposing them to increase by one fourth, are as follow: —

Numbers . .	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4
Squares . .	9	$10\frac{9}{16}$	$12\frac{1}{4}$	$14\frac{1}{16}$	16

From this small tabular view it may be inferred that if a root contain a fraction, its square also contains one. Thus, let the root be $1\frac{3}{12}$, its square is $\frac{225}{144}$, or $1\frac{81}{144}$, that is, rather more than half as great again as the integer 1.

580. Generally, when the root is a the square root must be aa; if the root be $2a$ the square will be $4aa$; from which it is evident that by doubling the root the square becomes 4 times greater; for if the root be $4a$, the square is $16aa$. If the root be ab, the square is $aabb$; if abc, the square is $aabbcc$.

581. Thus, then, if the root be composed of more factors than one, their squares must be multiplied together; and, reciprocally, if a square be composed of more than one factor whereof each is a square, it is only necessary to multiply the roots of these squares to obtain the complete square of the root proposed. Thus, as 5184 is equal to $9 \times 16 \times 36$, the square root of it is $3 \times 4 \times 6$, or 72; and 72, it will be seen, is the true square root of 5184; for 72×72 gives 5184.

582. Here we must for a moment stop to see how the signs + and − affect our operations: and, first, it cannot be doubted that if the root is a positive quantity, that is, with the sign + before it, its square must be a positive quantity; for + by + makes +: thus, the square of $+a$ will be $+aa$. So, also, if the root be a negative number, as $-a$, the square will still be positive, for it is $+aa$; from which it follows that of $+a$, as well as $-a$, the square is $+aa$; hence every square has two roots, one positive and the other negative. For example, the square of 16 is both +4 and −4, because −4 multiplied by −4 gives 16, as well as +4 by +4.

SQUARE ROOTS, AND THE IRRATIONAL NUMBERS THAT RESULT FROM THEM.

583. In the last section it has been seen that the square root of any number is but one whose square is equal to the given number, and that to those roots the positive or negative sign may be prefixed; so that if we could remember a sufficient number of squares, their roots would at the same time present themselves to our mind. Thus, if 144 were the given number, we should at once recollect that its square root is 12.

584. For the same reason fractions would be easily managed; for we at once see that $\frac{5}{7}$ is the square root of $\frac{25}{49}$, inasmuch as we have only to take the square root of the numerator and that of the denominator to be convinced of it.

If we have to deal with a mixed number, we have only to put it in the shape of a single fraction: for example, $12\frac{1}{4}$ is equivalent to $\frac{49}{4}$; and we see by inspection that $\frac{7}{2}$ or $3\frac{1}{2}$ must be the square root of $12\frac{1}{4}$. But when the given number is not a square, as, for example, 12, it is not possible to extract its square root, that is, to find a number multiplied by itself whose product is 12. It is, however, clear that the square root of 12 is greater than 3; for 3×3 produces only 9; and it must be less than 4, because 4×4 produces 16, which is greater than 12. From the table just given we may see that the square of $3\frac{1}{2}$ or $\frac{7}{2}$ is $12\frac{1}{4}$; hence the root must be less than $3\frac{1}{2}$. We may, however, come nearer to this root by comparing it with $3\frac{7}{15}$; for the square of $3\frac{7}{15}$, or of $\frac{52}{15}$, is $\frac{2704}{225}$, or $12\frac{4}{225}$, a fraction only greater by $\frac{4}{225}$ than the root required. Now, as $3\frac{1}{2}$ and $3\frac{7}{15}$ are both greater than the root of 12, it might be possible to add to 3 a fraction a little less than $\frac{7}{15}$, precisely such that the square of such sum should be exactly equal to 12. Trying, therefore, with $3\frac{3}{7}$, $\frac{3}{7}$ being a little less than $\frac{7}{15}$, we have $3\frac{3}{7}$, equal to $\frac{24}{7}$, whose square is $\frac{576}{49}$, and consequently less than 12 by $\frac{12}{49}$; because 12 may be expressed by $\frac{588}{49}$. Hence we perceive that $3\frac{3}{7}$ is less and $3\frac{7}{15}$ is greater than the root required. Trying a number, $3\frac{5}{11}$, which is a little greater than $3\frac{3}{7}$, but less than $3\frac{7}{15}$, its equivalent is $\frac{38}{11}$, and it will have for its square $\frac{1444}{121}$; and as 12 reduced to the same denominator is $\frac{1452}{121}$, we thus find that $3\frac{5}{11}$ is as yet less by $\frac{8}{121}$ than the root of 12. If for $\frac{5}{11}$ the fraction $\frac{6}{13}$, which is a little greater, be substituted, we have the square of $3\frac{6}{13}$, equal to $\frac{2025}{169}$; and 12 reduced to the same denominator, or multiplied by 169, equal to $\frac{2028}{169}$; so that $3\frac{6}{13}$ is yet too small, though only by $\frac{3}{169}$, whilst $3\frac{7}{15}$ has been found too great. From this it is evident that whatever fraction be joined to 3, the square of that sum will always contain a fraction, and will not be equal exactly to the integer 12. For, knowing that the square root of 12 is greater than $3\frac{6}{13}$, and less than $3\frac{7}{13}$, we are nevertheless unable to assign between the two an intermediate fraction, which, added to 3, precisely expresses the square root of 12. But it must not therefore be said that the square root of 12 cannot be absolutely determined, but only that it cannot be expressed by fractions.

585. We hence find that there exists a species of numbers which, though not expressible by fractions, are yet determinate quantities, and of this the square root of 12 furnishes an example. This species of numbers are termed *irrational numbers*, and occur as often as we attempt to find the square root of a number which is not a square. Thus, 2 not being a perfect square, its square root, or the number which, multiplied by itself, would produce 2, is an irrational quantity. Such numbers are also called *surd quantities*, or *incommensurables;* and though they cannot be expressed by fractions, they are, nevertheless, magnitudes of which an accurate idea may be formed. In the case of the number 12, for example, though its square root is not apparent, we know that it is a number which, multiplied by itself, would exactly produce 12; and this is a property which, by the power of approximating to it, is enough to enable us to form some idea of it.

586. Having now obtained a distinct idea of the nature of these irrational numbers, we must introduce to the reader the use of the sign $\surd$ (square root), which is used to express the square roots of all numbers that are not perfect squares. Thus $\surd 12$ signifies or represents the square root of 12, or that number which, multiplied by itself, produces 12. So $\surd 2$ represents the square root of 2, $\surd\frac{2}{3}$ that of $\frac{2}{3}$, and, generally, $\surd a$ represents the square root of the number a. If, therefore, we have at any time to express the square root of a number, all that is necessary is, to prefix to it the sign $\surd$. This explanation of irrational numbers enables us to apply to them the known methods of calculation. For, inasmuch as the square root of 2 multiplied by itself must produce 2, we know that $\surd 2 \times \surd 2$ will produce 2, and that $\surd\frac{2}{3} \times \surd\frac{2}{3}$ makes $\frac{2}{3}$; and so of any other number, and, generally, that $\surd a \times \surd a$ produces a.

587. When, however, it is required to multiply $\surd a$ by $\surd b$, the product is $\surd ab$, for it has been heretofore shown that when a square has two or more factors, its root is composed of the roots of those factors. Hence we find the square root of the product ab, which is $\surd ab$, by multiplying the square root of a, or $\surd a$, by the square root of b, or $\surd b$. And from this it is evident that if b were equal to a, $\surd aa$ would be the product of $\surd a$ by $\surd b$. Now, there can be no doubt that $\surd aa$ must be a, for aa is the square of a.

588. In division, if it be required to divide $\surd a$ by $\surd b$, the quotient must be $\surd\frac{a}{b}$, in which it may be, that the irrational number may vanish in the quotient. Thus, in the case of dividing $\surd 18$ by $\surd 8$, the quotient is $\surd\frac{18}{8}$, which is reduced to $\surd\frac{9}{4}$, and, consequently, to $\frac{3}{2}$, $\frac{9}{4}$ being the square of $\frac{3}{2}$.

589. When the number to which the radical sign $\surd$ is prefixed happens to be a square, the expression of the root follows the ordinary course. Thus, $\surd 4$ is equivalent to 2; $\surd 9$ is the same as 3; $\sqrt{81}$ the same as 9; and $12\frac{1}{4}$ the same as $\frac{7}{2}$ or $3\frac{1}{2}$; in which instances the irrationality is but apparent, and vanishes.

590. No difficulty occurs in multiplying irrational by ordinary numbers. Thus 2 multiplied by $\surd 5$ produces $2\surd 5$, and 3 multiplied by $\surd 2$ produces $3\surd 2$. In the last instance, however, as 3 is equal to $\surd 9$, the expression is also 3 times $\surd 2$ by $\surd 9$ multiplied by $\surd 2$ or by $\surd 18$. In the same way of considering this matter, $2\surd a$ is the same as $\surd 4a$, and $3\surd a$ is equivalent to $\surd 9a$. Generally, $b\surd a$ is equivalent to the square root of bba or $\sqrt{abb}$; and, reciprocally, when the number preceded by the radical sign contains a square, the root of the square may be prefixed to the sign, as in writing $b\surd a$ instead of $\surd bba$. From this it will be easy to comprehend the following expressions: —

$$\left.\begin{array}{l} \surd\ 8 \text{ or } \sqrt{2\cdot 4} \\ \surd 12 \text{ or } \sqrt{3\cdot 4} \\ \surd 18 \text{ or } \sqrt{2\cdot 9} \\ \surd 24 \text{ or } \sqrt{6\cdot 4} \\ \surd 32 \text{ or } \sqrt{2\cdot 16} \\ \surd 75 \text{ or } \sqrt{3\cdot 25} \end{array}\right\} \text{ is equivalent to } \left\{\begin{array}{l} 2\surd 2 \\ 2\surd 3 \\ 3\surd 2 \\ 2\surd 6 \\ 4\surd 2 \\ 5\surd 3 \end{array}\right.$$

On the foregoing principles the operations of division are based, for $\surd a$ divided by $\surd b$ must be $\frac{\surd a}{\surd b}$ or $\surd\frac{a}{b}$, and thus —

$$\left.\begin{array}{l} \frac{\surd 8}{\surd 2} \\ \frac{\surd 18}{\surd\ 2} \\ \frac{\surd 12}{\surd\ 3} \end{array}\right\} \text{ is equal to } \left\{\begin{array}{l} \surd\frac{8}{2} \text{ or } \surd 4\text{, that is, } 2 \\ \surd\frac{18}{2} \text{ or } \surd 9\text{, that is, } 3 \\ \surd\frac{12}{3} \text{ or } \surd 4\text{, that is, } 2 \end{array}\right.$$

And again —

$$\left.\begin{array}{c}\frac{2}{\sqrt{2}}\\ \frac{3}{\sqrt{3}}\\ \frac{12}{\sqrt{6}}\end{array}\right\}\text{ is equal to }\left\{\begin{array}{l}\frac{\sqrt{4}}{\sqrt{2}}\text{ or }\sqrt{\frac{4}{2}}\text{ or }\sqrt{2}\\ \frac{\sqrt{9}}{\sqrt{3}}\text{ or }\sqrt{\frac{9}{3}}\text{ or }\sqrt{3}\\ \frac{\sqrt{144}}{6}\text{ or }\sqrt{\frac{144}{6}}\text{ or }\sqrt{24},\text{ or }\sqrt{6\times 4};\text{ or, lastly, }2\sqrt{6}.\end{array}\right.$$

591. It is unnecessary to follow this out in division and subtraction, because the numbers are merely connected by the signs + and −. For example, $\sqrt{2}$ added to $\sqrt{3}$ is expressed $\sqrt{2}+\sqrt{3}$; and $\sqrt{6}$ subtracted from $\sqrt{10}$ is written $\sqrt{10}-\sqrt{6}$.

592. For the purpose of distinguishing these numbers from all others not similarly circumstanced, the latter, as well integral as fractional, are denominated *rational numbers*; and thence, when we speak of rational numbers, it is to be understood that we speak of integers or fractions.

IMPOSSIBLE OR IMAGINARY QUANTITIES.

593. The squares of numbers, whether negative or positive, as we have shown above, are always affected by the + or positive sign, for it has been seen that $-a$ multiplied by $-a$ produces $+aa$, in the same way as $+a$ by $+a$ produces the same result; and it was on this account that in the preceding section all the numbers whose roots were to be extracted were considered positive. If, however, the root of a negative number is to be extracted, a difficulty arises, because there is no assignable number whose square would be a negative quantity. If, for instance, we wanted the root of -4, we have to search for a number which, multiplied by itself, will produce -4. This number can be neither $+2$ nor -2, because the squares of both will be $+4$, and not -4. Hence we must conclude that the square root of a negative number is neither positive nor negative, inasmuch as that the squares of negative numbers are affected by the sign +. The root must, therefore, belong to a species of numbers entirely distinct from all others, for it cannot be placed among either positive or negative numbers.

594. It has been observed that all positive numbers are greater than 0, and that all negative numbers are less than 0; hence whatever exceeds 0 is a positive number, and that which is less than 0 must be expressed by negative numbers. Thus the square roots of negative numbers are neither greater nor less than nothing. But they are not 0, because the product of 0 multiplied by 0 is 0, and does not, therefore, produce a negative number. But as all conceivable numbers are greater or less than 0, or are 0 itself, the square root of a negative number cannot be ranked among possible numbers; hence it is said to be an impossible quantity; and it is this which leads us to an idea of numbers which are naturally impossible. They are usually called *imaginary quantities*, from their existing only in imagination. Such expressions, therefore, as $\sqrt{-1}$, $\sqrt{-2}$, $\sqrt{-3}$, $\sqrt{-4}$, &c. are impossible or imaginary numbers, because they represent roots of negative quantities; and of such numbers it may be said that they are neither nothing nor greater nor less than nothing; they are, therefore, imaginary or impossible. Though existing only in our imagination, we may form a sufficient idea of them, for we know that $\sqrt{-4}$ expresses a number which, multiplied by itself, produces -4. For this reason there is nothing to prevent, in calculation, the use of these imaginary numbers.

595. The most obvious idea on the above matter is, that the square of $\sqrt{-3}$, for instance, or the product of $\sqrt{-3}$ by $\sqrt{-3}$ will be -3; that the product of $\sqrt{-1}$ by $\sqrt{-1}$ is -1; and, in general, that by multiplying $\sqrt{-a}$ by $\sqrt{-a}$ we obtain $-a$. Now $-a$ is equal to $+a$ multiplied by -1, and as the square root of a product is found by multiplying together the roots of its factors, it follows that the root of a multiplied by -1 or $\sqrt{-a}$ is equal to $\sqrt{a}$ multiplied by $\sqrt{-1}$. But $\sqrt{a}$ is a possible or real number, consequently the whole impossibility of an imaginary quantity may be always reduced to $\sqrt{-1}$. Thus $\sqrt{-4}$ is equal to $\sqrt{4}$ multiplied by $\sqrt{-1}$, and equal also to $2\sqrt{-1}$, for the $\sqrt{4}$ is equal to 2; and so also $\sqrt{-9}$ is reduced to $\sqrt{9}\times\sqrt{-1}$ or $3\sqrt{-1}$, and similarly $\sqrt{-16}$ is equal $4\sqrt{-1}$. Thus, also, as $\sqrt{a}$ multiplied by $\sqrt{b}$ produces $\sqrt{ab}$, we have $\sqrt{6}$ for the value of $\sqrt{-2}$ multiplied by $\sqrt{-3}$; and $\sqrt{4}$ or 2 for the value of the product of $\sqrt{-1}$ by $\sqrt{-4}$. Hence we see how two imaginary numbers multiplied together produce one which is real or possible. But, on the other hand, a possible number multiplied by an impossible one always produces an imaginary product: thus, $\sqrt{-3}$ by $\sqrt{+5}$ gives $\sqrt{-15}$.

596. The same species of results prevail in division; for, as $\sqrt{a}$ divided by $\sqrt{b}$ makes $\frac{\sqrt{a}}{\sqrt{b}}$, it is clear that $\sqrt{-4}$ divided by $\sqrt{-1}$ will make $\sqrt{+4}$ or 2, that $\sqrt{+3}$ divided by $\sqrt{-3}$ gives $\sqrt{-1}$; and that 1 divided by $\sqrt{-1}$ gives $\sqrt{\frac{+1}{-1}}$ or $\sqrt{-1}$, because 1 is equal to $\sqrt{+1}$. It has been already stated that the square root of a number has universally two values, one positive and the other negative; that $\sqrt{4}$, for example, is both $+2$ and -2; and that, generally, $-\sqrt{a}$ as well as $+\sqrt{a}$ exhibit equally the square root of a. It is

the same in the case of imaginary numbers, for the square root of $-a$ is both $+\sqrt{-a}$ and $-\sqrt{-a}$, but the signs $+$ and $-$ before the radical sign $\sqrt{}$ must not be confounded with the signs that come after it.

597. However, on first view, it may seem idle speculation thus to dwell on impossible numbers, the calculation of imaginary quantities is of the greatest importance, for questions constantly arise wherein it is impossible to say whether anything real or possible is or is not included, and when the solution of such a question leads to imaginary quantities, we are certain that what is required is impossible. Thus, suppose it were required to divide the number 12 into two such parts that the product of them may be 40. In resolving this question by the ordinary rules we find, for the parts sought, $6+\sqrt{-4}$ and $6-\sqrt{-4}$, both imaginary numbers; hence we know that it is impossible to resolve the question. The difference is manifest in supposing the question had been to divide 12 into two parts whose product should produce 35, for it is evident that those parts must be 7 and 5.

598. A number twice multiplied by itself, or its square multiplied by the root, produces *a cube* or *cubic number.* Thus the cube of a is aaa, for it is the product of a multiplied by a, and that square aa again multiplied by a.

The cubes of the natural numbers are placed in the subjoined table: —

Numbers	1	2	3	4	5	6	7	8	9	10
Cubes	1	8	27	64	125	216	343	512	729	1000

Analysing the differences of these cubes, as we did those of the squares, by subtracting each cube from that following, the following series of numbers occur: —

7, 19, 37, 61, 91, 127, 169, 217, 271,

And in these there does not appear any regularity; but, taking the differences of these, we shall have the following series: —

12, 18, 24, 30, 36, 42, 48, 54, 60;

On the inspection of which it will be seen that the terms increase regularly by 6.

599. From the definition of a cube the cubes of fractional numbers are easily found: thus, $\frac{1}{8}$ is the cube of $\frac{1}{2}$, $\frac{1}{27}$ is the cube of $\frac{1}{3}$, and $\frac{8}{27}$ is the cube of $\frac{2}{3}$. Thus, also, we have only to take the cube of the numerator and that of the denominator separately, and for the cube of $\frac{3}{4}$ we have $\frac{27}{64}$. To find the cube of a mixed number it must be reduced, first to a single fraction, and the process is then conducted in a similar manner. Thus, to find the cube of $1\frac{1}{4}$ we must take the cube of $\frac{5}{4}$, which is $\frac{125}{64}$ or $1\frac{61}{64}$, and the cube of $1\frac{1}{2}$ is that of $\frac{3}{2}$, or $\frac{27}{8}$, or $3\frac{3}{8}$.

As aaa is the cube of a, that of ab will be $aaabbb$; from which we learn, that if a number has two or more factors, its cube may be found by multiplying together the cubes of those factors. For instance, as 12 is equal to 3 × 4, the cube of 3, which is 27, if multiplied by the cube of 4, which is 64, gives us 1728, the cube of 12. Again, the cube of $2a$ is $8aaa$, that is to say, 8 times greater than the cube of a; so the cube of $4a$ is $64aaa$, that is to say, 64 times greater than the cube of a.

600. The cube of a positive number will, of course, be positive: thus, that of $+a$ will be $+aaa$; but the cube of a negative will be negative, for $-a$ by $-a$ gives $+aa$, and that again multiplied by $-a$ gives $-aaa$. So that it is not the same as with squares, for these are always positive.

CUBE ROOTS AND THE IRRATIONAL NUMBERS THAT RESULT FROM THEM.

601. As we can, by the mode above given, find the cube of any given number, so may we find one which, multiplied twice by itself, will produce that number. With relation to the cube this is called the *cube root*, or that whose cube is equal to the given number. When the number proposed is a real cube the solution is easy enough. For there is no difficulty in seeing that the cube of 1 is 1, that that of 8 is 2, that of 4 is 64, and so on: and equally that the cube root of -27 is -3, and that of -216 is -6. Similarly, if the proposed number be a fraction, as $\frac{8}{125}$, the cube root is $\frac{2}{5}$, and that of $\frac{27}{343}$ is $\frac{3}{7}$. And last, in the case of a mixed number, as $2\frac{10}{27}$, the cube root will be $\frac{4}{3}$ or $1\frac{1}{3}$, because $2\frac{10}{27}$ is equal to $\frac{64}{27}$.

602. If, however, the proposed number be not a cube, its cube root cannot be expressed either in integers or fractional numbers. Thus, 43 is not a cube number; hence it is impossible to assign any number, integer or fractional, whose cube shall be exactly 43. We may, however, assert that the cube root of that number is greater than 3, for the cube of 3 is only 27, and less than 4, because the cube of 4 is 64. The cube root required lies, therefore, between 3 and 4. The cube root of 43 being greater than 3, by adding a fraction to 3 we may approach nearer to the value of the root, but we shall never be able to express the value exactly, because the cube of a mixed number can never be exactly equal to an integer, as 43 for instance. If we suppose $3\frac{1}{2}$ or $\frac{7}{2}$ to be the cube root required,

the error would be $\frac{1}{8}$, for the cube of $\frac{7}{2}$ is only $\frac{343}{8}$ or $42\frac{7}{8}$. Thus we see that the cube root of 43 can be expressed neither by integers nor fractions. We obtain, however, a distinct notion of its magnitude, and, for the purpose of representing it, a sign $\sqrt[3]{\ }$ is placed before the number which is read *cube root*, to distinguish it from the square root, which is frequently merely called the root. Thus $\sqrt[3]{43}$ expresses the cube root of 43, that is, the number whose cube is 43.

603. It is evident that such expressions cannot belong to rational quantities, and that, indeed, they form a particular species of irrational quantities. Between them and square roots there is nothing in common, and it is impossible to express such a cube root by a square root, as, for example, by $\sqrt{12}$, for the square of $\sqrt{12}$ being 12, its cube will be $12\sqrt{12}$, consequently irrational, and such cannot be equal to 43.

604. If the proposed number be a real cube the expressions become rational: $\sqrt[3]{1}$ is equal to 1; $\sqrt[3]{8}$ is equal to 2; $\sqrt[3]{27}$ is equal to 3; and, generally, $\sqrt[3]{aaa}$ is equal to a.

605. If it be proposed to multiply one cube root by another, $\sqrt[3]{a}$, for example, by $\sqrt[3]{b}$, the product must be $\sqrt[3]{ab}$; for it has already been seen that the cube root of a product ab is found by multiplying together the cube root of its factors. Whence, also, if $\sqrt[3]{a}$ be divided by $\sqrt[3]{b}$, the quotient will be $\sqrt[3]{\frac{a}{b}}$. And, further, $2\sqrt[3]{a}$ is equal to $\sqrt[3]{8a}$, for 2 is the same as $\sqrt[3]{8}$; $3\sqrt[3]{a}$ is equal to $\sqrt[3]{27a}$, and $b\sqrt[3]{a}$ is the same as $\sqrt[3]{abbb}$. So, reciprocally, when the number under the radical sign has a factor which is a cube, we may always get rid of it by placing its cube root before the sign. Thus, instead of $\sqrt[3]{64a}$ we may write $4\sqrt[3]{a}$, and $7\sqrt[3]{a}$ instead of $\sqrt[3]{343a}$. Hence $\sqrt[3]{16}$ is equal to $2\sqrt[3]{2}$, because 16 is equal to 8×2. When a number proposed is negative, its cube root is not subject to the difficulties which we observed in speaking of square roots; for, as the cubes of negative numbers are negative, it follows that their cube roots are but negative. Thus $\sqrt[3]{-8}$ is equal to -2, and $\sqrt[3]{-27}$ to -3. So also $\sqrt[3]{-12}$ is the same as $-\sqrt[3]{12}$, and $\sqrt[3]{-a}$ may be expressed by $-\sqrt[3]{a}$. From which it may be deduced that the sign $-$, though found after the sign of the cube root, might have been as well placed before it. Hence we do not herein fall upon impossible or imaginary quantities, as we did in considering the square roots of negative numbers.

OF POWERS IN GENERAL.

606. A *power* is that number which is obtained by multiplying a number several times by itself. A square arises from the multiplication of a number by itself, a cube by multiplying it twice by itself, and these are powers of the number. In the former case we say the number is raised to the second degree or to the second power; and in the latter, the number is raised to the third degree or to the third power.

607. These powers are distinguished from one another by the number of times that the given number has been multiplied by itself. Thus the square is called the second power, because it has been removed to the second product by multiplication by itself; another multiplication by itself brings it to the third power or cube. When multiplied again by itself it becomes the fourth power, which is commonly called the *bi-quadrate*. From this will be readily comprehended what is meant by the fifth, sixth, seventh, &c. power of a number. After the fourth degree the names of the powers have only numeral distinctions. For the purpose of illustration, we may observe, that the powers of 1 must always be 1, decause how often soever we multiply 1 into itself the product must be 1. The following table shows the powers of 2 and 3.

Powers.	Of the number 2.	Of the number 3.
I	2	3
II	4	9
III	8	27
IV	16	81
V	32	243
VI	64	729
VII	128	2187
VIII	256	6561
IX	512	19683
X	1024	59049
XI	2048	177147
XII	4096	531441
XIII	8192	1594323
XIV	16384	4782969
XV	32768	14348907
XVI	65536	43046721
XVII	131072	129140163
XVIII	262144	387420489

608. Of powers, those of the number 10 are the most remarkable, as being the foundation of our system of arithmetic. We will range in order a few of them, as under: —

I, II, III, IV, V, VI,
10, 100, 1000, 10000, 100000, 1000000, &c.

To consider which more generally, we may take the powers of any number *a*, as placed in the following order: —

I, II, III, IV, V, VI,
a, *aa*, *aaa*, *aaaa*, *aaaaa*, *aaaaaa*, &c.

But in this mode of writing powers there is much inconvenience, because of the trouble of counting the figures and letters; for the purpose of ascertaining the powers intended to be represented, as, for example, the inconvenience of representing the hundredth power would be so great as to incumber almost to impossibility the expression of it. To avoid this inconvenience, an expedient has been devised which is sufficiently convenient, and which we have now to explain. To express, for example, the hundredth power of *a*, we write just above it to the right the power in question; thus, a^{100} means, conventionally, *a* raised to the hundredth power. The number thus written above that whose power or degree it represents is called an *exponent*, from its expounding the power or degree to which the number is to be raised, which, in the example we have adduced, is 100. Thus, then, a^2 represents the square or second power of *a*, which, as we have seen, may be also represented by *aa*, either of these expressions being understood with equal facility. To express the cube or third power of *a* or *aaa*, a^3 is written, by which mode less room is occupied. So a^4, a^5, a^6, &c. respectively represent the fourth, fifth, and sixth powers of *a*. We may in this manner represent *a* by a^1, which, in fact, shows nothing more than that this letter is to be written only once. Such a series of powers as we here have noticed is called also a *geometrical progression*, because each term is once greater than the preceding.

609. As in this series of powers each term increases by multiplying the preceding term by *a*, thereby increasing the exponent by 1, so where any term is given the preceding one may be found if we divide by *a*, because it diminishes the exponent by 1: thus showing that the first term a^1 must necessarily be $\frac{a}{a}$ or 1; hence, if we proceed according to the exponents, we immediately perceive that the term which precedes the first must be a^0, from which follows this remarkable property, that a^0 is always equal to 1, however great or small the value of the number *a* may be, even if *a* be nothing.

610. The series of powers may be continued in a retrograde order, and in two different ways: first, by dividing continually by *a*; and, secondly, by diminishing the exponent by unity. In either mode the terms will be equal. The decreasing series, exhibited in both forms, is shown in the subjoined table, which is to be read from right to left.

	$\frac{1}{aaaaaa}$	$\frac{1}{aaaaa}$	$\frac{1}{aaaa}$	$\frac{1}{aaa}$	$\frac{1}{aa}$	$\frac{1}{a}$	1	a
First -	$\frac{1}{a}$	$\frac{1}{a^5}$	$\frac{1}{a^4}$	$\frac{1}{a^3}$	$\frac{1}{a^2}$	$\frac{1}{a}$		
Second -	a^{-6}	a^{-5}	a^{-4}	a^{-3}	a^{-2}	a^{-1}	a^0	a^1

Thus we come to the knowledge of powers whose exponents are negative, and are able to assign the precise value of those powers. And hence, from what has been said, it will be apparent that

$$\left.\begin{array}{r} a^0 \\ a^{-1} \\ a^{-2} \\ a^{-3} \\ a^{-4} \end{array}\right\} \text{is equal to} \left\{\begin{array}{l} 1 \\ \frac{1}{a} \\ \frac{1}{aa} \text{ or } \frac{1}{a^2} \\ \frac{1}{a^3} \\ \frac{1}{a^4} \quad \text{\&c.} \end{array}\right.$$

This gives us the facility of finding the powers of a product *ab*; for they must be evidently *ab*, or a^1b^1, a^2b^2, a^3b^3, a^4b^4, a^5b^5, &c.; and the powers of fractions are found in the same manner; for example, those of $\frac{a}{b}$ are

$$\frac{a^1}{b^1}, \frac{a^2}{b^2}, \frac{a^3}{b^3}, \frac{a^4}{b^4}, \frac{a^5}{b^5}, \frac{a^6}{b^6}, \text{\&c.}$$

The only matter remaining, then, is the consideration of the powers of negative numbers. Take, for example, the powers of $-a$, and they will form the following series: —

$$-a, \quad +aa, \quad -a^3, \quad +a^4, \quad -a^5, \quad +a^6, \text{ \&c.};$$

in which we immediately perceive that those powers are negative whose exponents are odd numbers, and that the powers with even numbers for exponents are positive. Thus the third, fifth, seventh, ninth, &c. powers have the sign $-$; and the second, fourth, sixth, eighth, &c. powers are affected by the sign $+$.

CALCULATION OF POWERS.

611. The addition and subtraction of powers is effected by means of the signs $+$ and $-$ when the powers are different; for example, a^3+a^2 is the sum of the third and second powers of a; and a^5-a^4 is the remainder when the fourth power of a is subtracted from the fifth; neither of which results can be abridged. If the powers are of the same kind or degree it is not necessary to connect them by signs, thus a^3+a^3 makes $2a^3$, &c.

612. But in the multiplication of powers, we must observe, first, that any power of a multiplied by a, gives the succeeding power, that is to say, the power whose exponent is one unit greater. Thus a^2 multiplied by a produces a^3; and a^3 multiplied by a produces a^4. Similarly, if it be required to multiply by a, the powers of that number having negative exponents, 1 must be added to the exponent. Thus, a^{-1} multiplied by a produces a^0 or 1; and this becomes most clearly seen by considering that a^{-1} is equal to $\frac{1}{a}$ and that the product of $\frac{1}{a}$ being $\frac{a}{a}$, it is consequently equal to 1. So a^{-2} multiplied by a produces a^{-1} or $\frac{1}{a}$, and a^{-5} multiplied by a produces a^{-4}, and so on.

613. If it be required to multiply a power of a by aa or the second power, the exponent then becomes greater by 2. Thus the product of a^2 by a^2 is a^4; that of a^2 by a^3 is a^5; that of a^3 by a^4 is a^6; and, generally, a^n multiplied by a^2 makes a^{n+2}. In the case of negative exponents, a^1 or a is the product of a^{-1} by a^2. For a^{-1} being the same as $\frac{1}{a}$, it is just the same as if we had divided aa by a; hence the product required is $\frac{aa}{a}$ or a. In the same way, a^{-2} multiplied by a^2 produces a^0 or 1, and a^{-3} multiplied by a^2 produces a^{-1}. It is equally clear that to multiply any power of a by a^3, its exponent must be increased by three units, consequently the product of a^n by a^3 is a^{n+3}. And as often as it is required to multiply two powers of a, the product must be a power of a whose exponent is equal to the sum of those of the two given powers. For instance, a^4 multiplied by a^6 will make a^9, and a^{12} multiplied by a^7 produces a^{19}, &c.

614. On the principles here exhibited, it is easy to determine the highest powers. Thus, to find the twenty-fourth power of 2, multiply the twelfth power by the twelfth power; because 2^{24} is equal to $2^{12} \times 2^{12}$. But we have already seen that 2^{12} is equal to 4096; hence the number 16777216, being the product of 4096 by 4096, is 2^{24}, or the required power of 2.

615. In division we must observe that to divide a power of a by a the exponent must be diminished by unity. Thus a^5 divided by a gives a^4; a^0 or 1 divided by a is equal to a^{-1} or $\frac{1}{a}$; a^{-3} divided by a gives a^{-4}. So, if we have to divide a given power of a by a^2, the exponent must be diminished by 2, and if by a^3, three units must be subtracted from the exponent of the power proposed; and, generally, if it be required to divide any power of a by any other power of a, the rule is to subtract the exponent of the second from the exponent of the first of those powers. Thus a^{16} divided by a^9 gives a^7; a^5 divided by a^6 will give a^{-1}. So a^{-3} divided by a^4 will give a^{-7}.

616. It is not difficult, then, from what has been said, to find the powers of powers, for it is effected by multiplication. Thus, if we have to seek the square or second power of a^3, we find a^6, and for the cube or third power of a^4 we have a^{12}. To obtain the square of a power it is only necessary to double the exponent; for its cube, to triple the exponent, and so on. Thus a^{2n} is the square of a^n, a^{3n} is the cube of a^n, and the seventh power of a^n is a^{7n}. The square of a^2, or square of the square of a, being a^4, is hence called *biquadrate*. The square of a^3 is a^6; hence the sixth power has received the name of the square-cubed. To conclude, the cube of a^3 being a^9, the ninth power has received the name of the *cubo-cube*.

ROOTS RELATIVELY TO POWERS IN GENERAL.

617. The square root of a given number is a number whose square is equal to that number; the cube root, that whose cube is equal to the given number: hence, whatever number be given, such roots of it will exist that their fourth, their fifth, or any other power, will be equal to the given number. For distinction sake, we shall call the square

root the *second root*, the cube root the *third root*, the bi-quadrate the *fourth root*, and so on. As the square or second root is marked by the sign $\sqrt{\ }$, and the cubic or third root by the sign $\sqrt[3]{\ }$; so the fourth and fifth roots are respectively marked by the signs $\sqrt[4]{\ }$ and $\sqrt[5]{\ }$, and so on. It is evident, according to this method of expression, the sign of the square root should be $\sqrt[2]{\ }$; but by common consent the figure is always left out; and we are to recollect that when a radical sign has no number prefixed to it, the square root is always meant. To give a still better explanation, we here subjoin some different roots of the number a, with their respective values: —

$$\left.\begin{array}{l}\sqrt{a}\\ \sqrt[3]{a}\\ \sqrt[4]{a}\\ \sqrt[5]{a}\\ \sqrt[6]{a}\end{array}\right\}\text{is the}\left\{\begin{array}{l}\text{2d}\\ \text{3d}\\ \text{4th}\\ \text{5th}\\ \text{6th}\end{array}\right\}\text{root of}\left\{\begin{array}{l}a\\ a\\ a\\ a\\ a\text{, and so on.}\end{array}\right.$$

And so, conversely,

$$\left.\begin{array}{l}\text{The 2d}\\ \text{The 3d}\\ \text{The 4th}\\ \text{The 5th}\\ \text{The 6th}\end{array}\right\}\text{power of}\left\{\begin{array}{l}\sqrt{a}\\ \sqrt[3]{a}\\ \sqrt[4]{a}\\ \sqrt[5]{a}\\ \sqrt[6]{a}\end{array}\right\}\text{is equal to}\left\{\begin{array}{l}a\\ a\\ a\\ a\\ a\text{, and so on.}\end{array}\right.$$

618. Whether a be a small or a great number, we know what value to affix to all these roots of different degrees. If unity be substituted for a the roots remain constantly 1; for all powers of 1 have unity for their value. But if the number a be greater than 1, the roots will also all exceed unity; and further, if a represent a less number than 1, all the roots will be less than unity.

619. When the number a is positive, from what has been before said of square and cube roots, we know that all the other roots may be determined, and that they will be real and possible numbers. But if the number a is negative, its second, fourth, sixth, and all even roots become impossible, or imaginary numbers; because all the powers of an even order, whether of positive or of negative numbers, are affected by the sign +; whereas the third, fifth, seventh, and all odd roots become negative, but rational, because the odd powers of negative numbers are also negative. Hence an inexhaustible source of new kinds of surd or irrational quantities; for, whenever the number a is not a power represented by some one of the foregoing indices, it is impossible to express the root either in whole numbers or fractions, and it must therefore be ranked among the numbers called irrational.

THE REPRESENTATION OF POWERS BY FRACTIONAL EXPONENTS.

620. In the preceding subsections we have seen that the square of any power is found by doubling its exponent, and that in general the square or second power of a^n is a^{2n}. Hence the converse, that the square root of the power a^{2n} is found by dividing the exponent of that power by 2. Thus the square root of a^2 is a^1; that of a^6 is a^3; and as this is general, the square root of a^3 is necessarily $a^{\frac{3}{2}}$, and that of a^7 is $a^{\frac{7}{2}}$. Thus we have $a^{\frac{1}{2}}$ for the square root of a^1, and hence $a^{\frac{1}{2}}$ is equal to $\sqrt{a}$; a new method of expressing the square root, which requires our particular attention.

621. To find the cube of a power, as a^n, we have already shown that its exponent must be multiplied by 3, hence its qube becomes a^{3n}; and, conversely, to find the third or cube root of the power a^{3n}, we have only to divide the exponent by 3; hence the root is a^n. Thus, also, a^1 or a is the cube root of a^3, a^2 that of a^6, a^4 that of a^{12}, and so on. The same reasoning is applicable to those cases in which the exponent is not divisible by 3; for it is evident that the cube root of a^2 is $a^{\frac{2}{3}}$, as the cube root of a^4 is $a^{\frac{4}{3}}$ or $a^{1\frac{1}{3}}$. Hence the third or cube root of a or a^1 will be $a^{\frac{1}{3}}$, which is the same as $\sqrt[3]{a}$.

622. The application is the same with roots of a higher degree: thus the fourth root of a will be $a^{\frac{1}{4}}$, which expression is of the same value as $\sqrt[4]{a}$. The fifth root of a will be $a^{\frac{1}{5}}$, which is equivalent to $\sqrt[5]{a}$, and so on in roots of higher degree. It would be possible, therefore, to dispense altogether with the radical signs, and to substitute fractional exponents for them; but as custom has sanctioned the signs, and as they are met with in all works on algebra, it would be wrong to banish them altogether from calculation. There is, however, sufficient reason to employ, as is frequently done, the other method of calculation; because it clearly corresponds with the nature of the thing. Thus, in fact, it is manifest that $a^{\frac{1}{2}}$ is the square root of a, because we know that its square is equal to a^1 or a.

623. What has been said will be sufficient to show how we are to understand fractional exponents; thus, if $a^{\frac{4}{3}}$ should occur, it means that we are first to take the fourth power of a and then extract its cube or third root, and hence $a^{\frac{4}{3}}$ is the same as $\sqrt[3]{a^4}$. Again, to find

the value of $a^{\frac{3}{4}}$ the cube or third power of a or a^3 must first be taken, and the fourth root of that power extracted, so that $a^{\frac{3}{4}}$ is the same as $\sqrt[4]{a^3}$. So $a^{\frac{4}{5}}$ is the same as $\sqrt[5]{a^4}$, &c. But when the fraction which represents the exponent is greater than unity, the value of the given quantity may be otherwise expressed. Let it, for instance, be $a^{\frac{5}{2}}$; now this quantity is equivalent to $a^{2\frac{1}{2}}$ which is the product of a^2 by $a^{\frac{1}{2}}$. Now $a^{\frac{1}{2}}$ is equal to $\sqrt{a}$, wherefore $a^{\frac{5}{2}}$ is equal to $a^2\sqrt{a}$. So $a^{\frac{10}{3}}$, or $a^{3\frac{1}{3}}$, is equal to $a^3\sqrt[4]{a^3}$; and $a^{\frac{15}{4}}$, that is, $a^{3\frac{3}{4}}$ expresses $a^3\sqrt{a^3}$. From these examples the use of fractional exponents may be properly appreciated. This, however, extends also to fractional numbers, as follows.

624. Suppose $\frac{1}{\sqrt{a}}$ is given, we know that it is equal to $\frac{1}{a^{\frac{1}{2}}}$; now we have already seen that a fraction of the form $\frac{1}{a^n}$ may be expressed by a^{-n}; and instead of $\frac{1}{\sqrt{a}}$, we may use the expression $a^{-\frac{1}{2}}$. Also, $\frac{1}{\sqrt[3]{a}}$ is equal to $a^{-\frac{1}{3}}$. So let the quantity $\frac{a^2}{\sqrt{a^3}}$ be proposed, it is transformable into $\frac{a^2}{a^{\frac{3}{2}}}$, which is the product of a^2 by $a^{-\frac{3}{2}}$, and this is equivalent to $a^{\frac{3}{2}}$, or to $a^{1\frac{1}{2}}$, or, lastly, to $\sqrt{a^5}$. These reductions will be facilitated by a little practice.

625. Each root may be variously represented, for $\sqrt{a}$ is the same as $a^{\frac{1}{2}}$, and $\frac{1}{2}$ being equivalent to the fractions $\frac{2}{4}$, $\frac{3}{6}$, $\frac{4}{8}$, $\frac{5}{10}$, $\frac{6}{12}$ &c., it is clear that $\sqrt{a}$ is equal to $\sqrt[4]{a^2}$, to $\sqrt[6]{a^3}$, to $\sqrt[8]{a^4}$, and so on. Similarly, $\sqrt[3]{a}$ is equal to $a^{\frac{1}{3}}$, and to $\sqrt[6]{a^2}$, to $\sqrt[9]{a^3}$, and to $\sqrt[12]{a^4}$. It is, moreover, manifest, that the number a, or a^1 might be represented by the following radical expressions:

$$\sqrt[2]{a^2},\ \sqrt[3]{a^3},\ \sqrt[4]{a^4},\ \sqrt[5]{a^5},\ \&c.$$

a property of great use in multiplication and division; for, suppose we have to multiply $\sqrt[2]{a}$ by $\sqrt[3]{a}$, we write $\sqrt[6]{a^3}$ for $\sqrt[2]{a}$, and $\sqrt[6]{a^2}$ instead of $\sqrt[3]{a}$, thus obtaining the same radical sign for both, and the multiplication being now performed, gives the product $\sqrt{a^5}$. A similar result arises from $a^{\frac{1}{2}+\frac{1}{3}}$, the product of $a^{\frac{1}{2}}$ multiplied by $a^{\frac{1}{3}}$, for $\frac{1}{2}+\frac{1}{3}$ is $\frac{5}{6}$, and, consequently, the product required is $a^{\frac{5}{6}}$, or $\sqrt[6]{a^5}$. If it were required to divide $\sqrt{a}$ or $a^{\frac{1}{2}}$ by $\sqrt[3]{a}$ or $a^{\frac{1}{3}}$, we should have for the quotient $a^{\frac{1}{2}-\frac{1}{3}}$, or $a^{\frac{3}{6}-\frac{2}{6}}$, that is, $a^{\frac{1}{6}}$, or $\sqrt[6]{a}$.

METHODS OF CALCULATION AND THEIR MUTUAL CONNECTION.

626. In the foregoing passages have been explained the different methods of calculation in addition, subtraction, multiplication, and division, the involution of powers, and the extraction of roots. We here propose to review the origin of the different methods, and to explain the connection subsisting among them, in order that we may ascertain if it be possible or not for other operations of the same kind to exist; an inquiry which will illustrate the subjects that have been considered. We shall, for this purpose, here introduce a new sign $=$, which means that equality exists between the quantities it is used to join, and is read *equal to*. Thus, if I write $a=b$, it means that a is equal to b; and so $3\times 8=24$.

627. Addition, the process by which we add two numbers together and find their sum, is the first mode of calculation that presents itself to the mind. Thus if a and b be two given numbers whose sum is expressed by c, we shall have $a+b=c$. So that, knowing the two numbers a and b, we are taught by addition how to find the number c. Recollecting this comparison $a+b=c$, the question may be reversed by asking in what way b can be found when we know the numbers a and c. Let us, then, ascertain what number must be added to a that the sum may be c. Now, suppose, for instance, $a=3$, and $c=8$, it is evident we must have $3+b=8$, and b will be found by subtracting 3 from 8. So, generally, to find b, we must subtract a from c, whence arises $b=c-a$; for, by adding a to both sides again, we have $b+a=c-a+a$, that is, as was supposed, $=c$. And this is the origin of subtraction, being, indeed, nothing more than an inversion of the question from which addition arises. Now it is possible that it may be required to subtract a greater from a lesser number; as, for example, 9 from 5. In this case we are furnished with the idea of a new kind of numbers, which are called negative numbers, because $5-9=-4$.

628. If several equal numbers are to be added together, their sum is found by multiplication, and is called a product. Thus ab expresses the product of the multiplication of a by b, or from a being added to itself b times. If this product be represented by c, we have $ab=c$, and we may, by the use of multiplication, determine the number c where the numbers a and b are known. Suppose, for example, $a=3$, and $c=15$, so that $3b=15$, we have to ascertain what number b represents, merely to find by what number b is to be multiplied, in order that the product may be 15, for to that is the question reduced: and this is division; for the number sought is found by dividing 15 by 3; hence, in general, the number b is found by dividing c by a, whence results the equation $b=\frac{c}{a}$.

But, frequently, the number c cannot be actually divided by the number a, the letter b having a determinate value; hence a new kind of numbers, called fractions, arises. For, suppose $a=4$, $c=3$, so that $4b=3$, in this case b cannot be an integer, but must be a fraction, and we shall find that b can be no more than $\frac{3}{4}$. Multiplication, then, as we have seen, arises from the addition of equal quantities; so, from the multiplication of several equal quantities together, powers are derived, and they are represented in a general manner by the expression a^b, which signifies that the number a must be multiplied by itself as often as is pointed out by the number b, which is called the exponent, whilst a is called the root, and a^b the power. If this power be represented by the letter c, we have $a^b=c$, an equation in which are found the letters a, b, c. In treating of powers, it has been shown how to find the power itself, that is, the letter c, when the root a and its exponent b are given. Suppose, for instance, $a=4$, and $b=3$, we shall have $c=4^3$, or the third power of 4, which is 64, whence $c=64$. If we wish to reverse this question, we shall find that there are two modes of doing it. Let, for instance, two of the three numbers a, b, and c be given. If it be required to find the third, it is clear that the question admits of three different suppositions, and hence, also, of three solutions. The case has been considered in which a and b were the numbers given; we may therefore suppose, further, that c and a or c and b are known, and that it is required to determine the third letter. Now, it must be observed, that between involution and the two operations which lead to it there is a great difference. For when, in addition, we reverse the question, there was only one way of doing it, and it was of no consequence whether we took c and a or c and b for the given numbers, for it is quite indifferent to the result whether we write $a+b$ or $b+a$. And it is quite the same with multiplication; the letters a and b might be placed in each other's places at pleasure, the equation $ab=c$ being exactly the same as $ba=c$. But in the calculation of powers, we cannot change the places of the letters; for instance, we could on no account write b^a for a^b. This we will illustrate by one example. Thus, let $a=4$, and $b=3$, we have $a^b=4^3=64$. But $b^a=3^4=81$, two very different results.

629. We may propose two more questions; one to find the root a by means of the given power c, and the exponent b; the other to find the exponent b, the power c and the root a being known. The former of these questions has been answered in the subsection which treats of the extractions of roots: since, if $b=2$, and $a^2=c$, we know that a is a number whose square is equal to c, and consequently $a=\sqrt{c}$. So, if $b=3$ and $a^3=c$, we know that the cube of a is equal to the given number c, and hence that $a=\sqrt[3]{c}$. We conclude, generally, from this, how the letter a may be determined by means of the letters c and b; for a must necessarily be $=\sqrt[b]{c}$.

630. We have already seen that if the given number is not a real power (a contingency of frequent occurrence), the required root a can be expressed neither by integers nor fractions; nevertheless, as it must have a determinate value, the same consideration led us to the numbers called *surd* or *irrational numbers*, which, on account of the great variety of roots, are divisible into an infinite number of kinds. We were also, by the same enquiry, led to the knowledge of imaginary numbers.

631. Upon the second question, that of determining the exponent by means of the power c and the root a, is founded the very important theory of logarithms; an invention so important that without them scarcely any long calculation could be effected.

LOGARITHMS.

632. Resuming, then, the equation $a^b=c$, we in the doctrine of logarithms assume for the root a number taken at pleasure, but supposed to preserve its assumed value without variation. This being the case, the exponent b is taken, such that the power a^b becomes equal to a given number c, and this exponent b is said to be the *logarithm* of the number c. To express this, we shall use the letter L or the initial letters *log*. Thus, by $b=\text{L}.c$ or $b=\log.c$, we mean that b is equal to the logarithm of the number c, or that the logarithm of c is b.

633. If the value of the root a is once established, the logarithm of any number c is but the exponent of that power of a which is equal to c. So that c being $=a$, b is the logarithm of the power of a. If we suppose $b=1$, we have 1 for the logarithm of a^1; hence $\text{L}.a=1$. Suppose $b=2$, we have 2 for the logarithm of a^2; that is $\text{L}.a^2=2$. Similarly, $\text{L}.a^3=3$, $\text{L}.a^4=4$, $\text{L}.a^5=5$, and so on.

634. If b be made $=0$, 0 must be the logarithm of a^0; but $a^0=1$; consequently, $\text{L}.1=0$, whatever the value of the root a. If $b=-1$, then -1 will be the logarithm of a^{-1}. Now $a^{-1}=\frac{1}{a}$; therefore, $\text{L}.\frac{1}{a}=-1$. So, also, $\text{L}.\frac{1}{a^2}=-2$; $\text{L}.\frac{1}{a^3}=-3$; $\text{L}.\frac{1}{a^4}=-4$; &c.

635. Thus, then, may be represented the logarithms of all the powers of a, and even those of fractions wherein unity is the numerator, and the denominator a power of a. We see, also, that, in all those cases, the logarithms are integers: but if b were a fraction it would be the logarithm of an irrational number. For suppose $b=\frac{1}{2}$, then $\frac{1}{2}$ is the logarithm of $a^{\frac{1}{2}}$, or of $\sqrt{a}$; consequently we have $\text{L}.\sqrt{a}=\frac{1}{2}$; and in the same way, $\text{L}.\sqrt[3]{a}=\frac{1}{3}$, $\text{L}.\sqrt[4]{a}=\frac{1}{4}$, &c.

636. If it be required to find the logarithm of another number c, it will be readily seen that it can neither be an integer nor a fraction. However, there must be such an exponent b, that the power a^b may become equal to the number proposed; we have, therefore, $b = \mathrm{L}.c$, and, generally, $a^{\mathrm{L}.c} = c$.

637. If we consider another number d, whose logarithm is represented in a similar manner by $\mathrm{L}.d$; then $a^{\mathrm{L}.d} = d$; and multiplying this expression by the preceding one $a^{\mathrm{L}.c} = c$, we have $a^{\mathrm{L}.c + \mathrm{L}.d} = cd$. The exponent being always the logarithm of the power $\mathrm{L}.c + \mathrm{L}.d = \mathrm{L}.cd$. If, instead of multiplying, we divide the former expression by the latter, we obtain $a^{\mathrm{L}.c - \mathrm{L}.d} = \frac{c}{d}$; hence $\mathrm{L}.c - \mathrm{L}.d = \mathrm{L}.\frac{c}{d}$.

638. From this we are led to the two principal properties of logarithms which are contained in the equations $\mathrm{L}.c + \mathrm{L}.d = \mathrm{L}cd$, and $\mathrm{L}.c - \mathrm{L}.d = \mathrm{L}.\frac{c}{d}$: by the former whereof we learn that the logarithm of a product, as cd, is found by adding together the logarithms of the factors; by the last, that the logarithm of a fraction is determined by the subtraction of the logarithm of the denominator from that of the numerator. Whence it follows that to multiply or divide two numbers by one another, we have only to add or subtract their logarithms. This constitutes the immense advantage of logarithms in calculation; for when a question is incumbered with large quantities, it is, of course, much easier to add or subtract than to multiply and divide. In the involution of powers and the extraction of roots, logarithms are yet more useful. Thus, if $d = c$, we have by the first property $\mathrm{L}.c + \mathrm{L}.c = \mathrm{L}.cc$; consequently, $\mathrm{L}.cc = 2\mathrm{L}.c$. Similarly, we have $\mathrm{L}.c^3 = 3\mathrm{L}.c$, $\mathrm{L}.c^4 = 4\mathrm{L}.c$, and, generally, $\mathrm{L}.c^n = n\mathrm{L}.c$.

Substituting fractional numbers for n, we shall have, for example, $\mathrm{L}.c^{\frac{1}{2}}$, that is $\mathrm{L}\sqrt{c} = \frac{1}{2}\mathrm{L}.c$. Lastly, if n represents negative numbers, we have $\mathrm{L}.c^{-1}$ or $\mathrm{L}.\frac{1}{c} = -\mathrm{L}.c$; $\mathrm{L}.c^{-2}$ or $\mathrm{L}.\frac{1}{cc} = 2\mathrm{L}.c$, and so on. For this not only follows from the equation $\mathrm{L}.c^n = n\ \mathrm{L}.c$, but also from $\mathrm{L}.1 = 0$, as we have before shown.

In tables of logarithms which are calculated for all numbers, great assistance is rendered in performing the most prolix calculations. Suppose, for instance, the square root of the number c is sought, having found the logarithm of c, which is $\mathrm{L}.c$, we have only to divide it by 2, that is, take the $\frac{1}{2}$ of it, and we have the logarithm of the square root required; and the number in the table answering to that logarithm is the number required.

We have seen that the numbers 1, 2, 3, 4, 5, 6, &c., that is, all positive numbers, are logarithms of the root a, and of its positive powers, and consequently logarithms of numbers greater than unity; and, on the other hand, that negative numbers, -1, -2, &c., are logarithms of the fractions $\frac{1}{a}$, $\frac{1}{aa}$, &c., which are less than unity, but, nevertheless, greater than nothing; from whence it follows, that if the logarithm be positive, the number is always greater than unity, but, if negative, the number, though less than one, is yet greater than 0. Thus we cannot express the logarithms of negative numbers, and must conclude that they are impossible, and belong to the class of imaginary quantities. That this may be better understood, let us fix on a determinate number for the root a, such, for instance, as the number 10, on which the common logarithmic tables are formed, and which is, moreover, the basis of our arithmetic. Any other number, however, provided it be greater than unity, would answer the same purpose. The reason why the $a = 1$ would not suit is, that all the powers would be but equal to unity.

LOGARITHMIC TABLES NOW USED.

639. We set out with the supposition that the root $a = 10$. Then the logarithm of any number c is the exponent to which the number 10 must be raised, so that the power resulting from it may be equal to the number c; or if we denote the logarithm of c by $\mathrm{L}.c$, we shall always have $10\mathrm{L}.c = c$.

The reader will recollect that the logarithm of 1 is always 0, and we have $10^0 = 1$. Hence—

$\mathrm{L}.1 = 0$, $\mathrm{L}.10 = 1$, $\mathrm{L}.100 = 2$, $\mathrm{L}.1000 = 3$, $\mathrm{L}.10000 = 4$, $\mathrm{L}.100000 = 5$, $\mathrm{L}.1000000 = 6$, &c.

Further, that

$\mathrm{L}.\frac{1}{10} = -1$, $\mathrm{L}.\frac{1}{100} = -2$, $\mathrm{L}.\frac{1}{1000} = -,3$ $\mathrm{L}.\frac{1}{10000} = -4$, $\mathrm{L}.\frac{1}{100000} = -5$, $\mathrm{L}.\frac{1}{1000000} = -6$, &c.

The logarithms of the principal numbers are therefore readily determined; but those between them, as inserted in the tables, are not so easy to find. Our object here, however, is only a general view of the subject, with which we shall proceed. And, first, since $\mathrm{L}.1 = 0$ and $\mathrm{L}.10 = 1$, it is manifest that the logarithms of all numbers between 1 and 10 lie between 0 and 1, that is greater than 0 and less than 1. Let us, then, consider the number 2, whose logarithm is certainly greater than 0, and yet less than unity. Now, if we represent this logarithm by the letter x, so that $\mathrm{L}.2 = x$, the value of x must be such as to give exactly $10x = 2$. We immediately see that x must be considerably less than $\frac{1}{2}$, or, which is the same thing, $10^{\frac{1}{2}}$ is greater than 2. For, squaring both sides, the square of $10^{\frac{1}{2}} = 10^1$, and that of $2 = 4$, which latter is much less than the former, So $\frac{1}{3}$ is still too great a value of x, that is to say, $10^{\frac{1}{3}}$ is greater than 2; for the cube of $10^{\frac{1}{3}}$ is 10, and that of 2 only 8. On the contrary, by making $x = \frac{1}{4}$, we give it too small a value; for the fourth power of 10 being 10, and that of 2 being 16, it is evident that $10^{\frac{1}{4}}$ is less than 2: x then, or L.2, is less than $\frac{1}{3}$, and yet greater than $\frac{1}{4}$. In the same way we may determine, with respect to every fraction contained between $\frac{1}{4}$ and $\frac{1}{3}$, whether it be too great or too small. Trying, for example, with $\frac{2}{7}$, which is a trifle less than $\frac{1}{3}$, and greater than $\frac{1}{4}$; 10^x or $10^{\frac{2}{7}}$ must $= 2$, or the seventh power of $10^{\frac{2}{7}}$, that is to say, 10^2 or 100 must be equal to the seventh power of 2; now the latter $= 128$, and is consequently greater than the former. Hence we infer that $10^{\frac{2}{7}}$ is also less than 2, and therefore that $\frac{2}{7}$ is less than L.2, and that L.2, which was found less than $\frac{1}{3}$, is, however, greater than $\frac{2}{7}$. We might proceed in this investigation, but it is here unnecessary; because, from what has been shown, we prove that L.2 has a determinate value; but continuing to represent it by x, so that $\text{L.}2 = x$, we will show that when once known, the logarithms of an infinity of other numbers may be deduced. For this purpose we will use the equation already mentioned, $\text{L.}cd = \text{L.}c + \text{L}d$, which comprehends the property, that the logarithm of a product is found by adding the logarithms of the factors.

640. First, as $\text{L.}2 = x$ and $\text{L.}10 = 1$, we have $\text{L.}20 = x + 1$; $\text{L.}200 = x + 2$, $\text{L.}2000 = x + 3$; $\text{L.}20000 = x + 4$ and $\text{L.}\ 200000 = x + 5$, &c.

Further, as $\text{L.}c^2 = 2\text{L.}c$, and $\text{L.}c^3 = 3\text{L.}c$, and $\text{L.}c^4 = 4\text{L.}c$, &c., we have $\text{L.}4 = 2x$; $\text{L.}8 = 3x$; $\text{L.}16 = 4x$; $\text{L.}32 = 5x$; $\text{L.}64 = 6x$, &c.; and from this it follows, that $\text{L.}40 = 2x + 1$; $\text{L.}400 = 2x + 2$; $\text{L.}4000 = 2x + 3$; $\text{L.}40000 = 2x + 4$, &c. Also, $\text{L.}80 = 3x + 1$, $\text{L.}800 = 3x + 2$, $\text{L.}8000 = 3x + 3$, $\text{L.}80000 = 3x + 4$, &c. So $\text{L.}160 = 4x + 1$, $\text{L.}1600 = 4x + 2$, $\text{L.}16000 = 4x + 3$, &c. Resuming the other fundamental equation $\text{L.}\frac{c}{d} = \text{L.}c - \text{L.}d$, let us suppose $c = 10$, and $d = 2$. Since $\text{L.}10 = 1$, and $\text{L.}2 = x$, we shall have $\text{L.}\frac{10}{2}$ or $\text{L.}5 = 1 - x$, from which the following equations are deduced:—

$$\text{L.}50 = 2 - x;\ \ \text{L.}500 = 3 - x;\ \ \text{L.}5000 = 4 - x,\ \&c.$$
$$\text{L.}25 = 2 - 2x;\ \ \text{L.}125 = 3 - 3x;\ \ \text{L.}625 = 4 - 4x,\ \&c.$$
$$\text{L.}250 = 3 - 2x;\ \ \text{L.}2500 = 4 - 2x;\ \ \text{L.}25000 = 5 - 2x,\ \&c.$$
$$\text{L.}1250 = 4 - 3x;\ \ \text{L.}12500 = 5 - 3x;\ \ \text{L.}125000 = 6 - 3x,\ \&c.$$
$$\text{L.}6250 = 5 - 4x;\ \ \text{L.}62500 = 6 - 4x;\ \ \text{L.}625000 = 7 - 4x,\ \&c.$$

and so on.

If we knew the logarithm of 3, we could determine another vast number of logarithms. For example: let the L.3 be expressed by y. Then $\text{L.}30 = y + 1$; $\text{L.}300 = y + 2$; $\text{L.}3000 = y + 3$, &c.; and $\text{L.}9 = 2y$; $\text{L.}27 = 3y$; $\text{L.}81 = 4y$; $\text{L.}243 = 5y$, &c.: as also $\text{L.}6 = x + y$; $\text{L.}12 = 2x + y$; $\text{L.}18 = x + 2y$, and $\text{L.}15 = \text{L.}3 + \text{L.}5 = y + 1 - x$.

From all this it is evident, that once knowing the logarithms of the prime numbers, the logarithms of all other numbers may be found by simple addition. Take, for example, the number 210, which is formed by the factors 2, 3, 5, 7, its logarithms will be $\text{L.}2 + \text{L.}3 + \text{L.}5 + \text{L.}7$. In the same manner the number $360 = 2 \times 2 \times 2 \times 3 \times 3 \times 5 = 2^3 \times 3^2 \times 5$; hence the $\text{L.}360 = 3\text{L.}2 + 2\text{L.}3 + \text{L.}5$. It is therefore to the logarithms of the prime numbers that we must first apply ourselves, if we desire to construct tables of logarithms.

METHOD OF EXPRESSING LOGARITHMS.

641. It has been shown that the logarithm of 2 is greater than $\frac{3}{10}$, and less than $\frac{1}{3}$, and that therefore the exponent of 10 lies between those two fractions, in order that the power may become $= 2$. But, although this is known to us, whatever fraction is assumed on this condition, the power resulting from it will always be an irrational number greater or less than 2; the logarithm, therefore, of 2 cannot be accurately expressed by such a fraction: hence we must be content with such an approximation to it as will render the error of no importance. For this purpose *decimal fractions* are used, which we shall now explain.

642. In the ordinary way of writing numbers by means of the ten figures or chararters

0, 1, 2, 3, 4, 5, 6, 7, 8, 9,

the first figure on the right hand is the only one which has its natural signification; the figures in the second place have ten times the value they would have had in the first; those in the third place have a hundred times the value, and those in the fourth a thousand times, and so on; so that in proportion as they advance towards the left, they acquire a value ten times greater than they had in the preceding rank. Thus, in the number 1849, the figure 9 is in the first place on the right, and is just equal to 9. That in the second place is 4, but this figure, instead of 4, represents 10×4 or 40 The figure 8 in the third place is equal to 100 × 8, or 800. Lastly, the 1, which is the fourth to the left, is equal to 1000, hence the number is read as follows, —

One thousand eight hundred and forty-nine.

643. As the value of figures becomes in each rank always ten times greater as we go from the right towards the left, and as it continually becomes less as we proceed from the left to the right, we may by this law advance still further towards the right, and obtain figures whose value may continually decrease and become ten times less; but where this occurs, the place where the figures cease to have their natural value will continue to become ten times less. In this case, however, the place where the figures have their natural value is marked by a point placed after that rank. Thus, if, for instance, we meet with the number 54·76938, it must be thus understood: — the figure 4 in the first place has its natural value, and the second 5 means 50; but the figure 7 which comes after the point expresses only $\frac{7}{10}$; the figure 6 is equal only to $\frac{6}{100}$; the figure 9 is equal to $\frac{9}{1000}$; the figure 3 to $\frac{3}{10000}$, and the figure 8 to $\frac{8}{100000}$; thus the more these figures advance towards the right, the more their values diminish, till at last those values become so small, that they may at last be considered as nothing. This species of numbers, then, are what are called *decimal fractions*, and in this way logarithms are represented in the tables. Thus the logarithm of 2 is expressed by 0·3010300, wherein we perceive, as the logarithm does not contain an integer, that its value is $\frac{3}{10}+\frac{0}{100}+\frac{1}{1000}+\frac{0}{10000}+\frac{3}{100000}+\frac{0}{1000000}+\frac{0}{10000000}$. The last two ciphers might have been omitted; they, however, serve to show that the logarithm quoted contains no parts which have 1000000 and 10000000 for the denominator. It is possible, however, that by continuing the series, smaller parts might have been found, which are neglected, except in extraordinary cases, on account of their extreme minuteness.

644. The logarithm of 3 is known by the tables to be 0·4771213, and, containing no integer, consists of the following fractions: — $\frac{4}{10}+\frac{7}{100}+\frac{7}{1000}+\frac{1}{10000}+\frac{2}{100000}+\frac{1}{1000000}+\frac{3}{10000000}$. This logarithm is, however, not expressed with the utmost exactness; we are only certain that the error is less than $\frac{1}{10000000}$, one so small, that there are few calculations in which it may not be neglected.

645. By this method of expressing logarithms, that of 1 will be represented by 0·0000000, since it is really $=0$. The logarithm of 10 is 1·0000000, or exactly $=1$. The logarithm of 100 is 2·0000000, or exactly $=2$. Hence the logarithms of all numbers between 10 and 100, and, consequently consisting of only two figures, must be comprehended between 1 and 2, and are, therefore, expressed by 1 + a decimal fraction. Thus L.50 = 1·6989700; its value, therefore, is unity added to $\frac{6}{10}+\frac{9}{100}+\frac{8}{1000}+\frac{9}{10000}+\frac{7}{100000}$. So it must be evident that between 100 and 1000 the logarithms of numbers are expressed by two integers with a decimal fraction; the logarithms of numbers between 10000 and 100000 by four integers joined to a decimal fraction, and so on. The *log.* 600, for example, is $=2·7781513$; that of 2460 is 3·3909351, &c. But the logarithms of numbers less than 10, or those expressed by a single figure, do not contain an integer, and for this reason we find an 0 before the point. Hence there are two parts of a logarithm which require consideration: the former, that which precedes the point, and denoting the integers, if any; the other, the decimal fractions to be added to the integers. The first part, or integer, of a logarithm, usually called the *characteristic*, is easily determined from what has been already shown, — that is, it is 0 for all the numbers having but one figure; 1 for those which have two; 2 for those which have three, and generally less by one unit than the number of figures. Hence, if the logarithm of 5682 be required, we immediately perceive that the first part, or that of the integers, must be 3. So, reciprocally, when we see the integers of a logarithm, since the number it expresses is greater by one unit than the integer of the logarithm, we know, at once, the number answering to it. Thus, having 4·4771213 for the logarithm of an unknown quantity, it is evident that the number must have five figures, and exceed 10000. Now this number is 30000 for *log.* 30000 = L.3 + L.10000. Now the logarithm of 3 is known to be equal 0·4771213, and the logarithm of 10000 = 4, and the sum of those logarithms = 4·4771213.

646. From this it will be seen that the first object in considering a logarithm is the decimal fraction following the point, because, when that is known, it will serve for several numbers. For the proof whereof let us take the number 456. Its first part must be 2; and if we represent the decimal fraction which follows it by x, we have L.456 $=2+x$. If we continue to multiply by 10, we find L.4560 $=3+x$; L.45600 $=4+x$; L.456000 $=5+x$, and so on. But, if we divide instead of multiply by 10, we shall have 45·6 $=1+x$; L.4·56 $=0+x$; L.0·456 $=-1+x$; L.0·0456 $=-2+x$; L.0·00456 $=-3+x$, and so on.

647. Thus, all the numbers arising from the figures 456, whether preceded or followed by ciphers, have the same decimal fraction for the second part of the logarithm, and their differences lie in the integer before the point, which becomes negative when the number is less than 1. As ordinary calculators have difficulty in the use of negative numbers, it is customary to increase the integers of the logarithm by 10, or to write 10

instead of 0 before the point: by which process, instead of -1 we have 9; instead of -2 we have 8; instead of -3 we have 7, &c. But, under these circumstances, it must be recollected that the characteristic has been made ten units too great; nor must we assume that the number consists of ten, nine, or eight figures. We may easily see, in the case in question, that if the characteristic be less than 10, the figures of the number must be written after a point. If the characteristic be 9, we must begin at the first place after a point; if it be 8, we must also place a cipher in the first row, and not begin to write the figures till the second. Thus 9·6589648 would be the logarithm of 0·456, and 8·6589648 the logarithm of 0·0456. This manner of using logarithms is, however, chiefly confined to the use of tables of sines.

648. Ordinary tables do not carry the decimals of logarithms further than seven places or figures, the last whereof must consequently represent the $\frac{1}{10000000}$th part, and we know that they do not err even by so small a part; the error, therefore, is of no importance in ordinary cases. But there are cases, though of no importance in our application of their use, in which still greater exactness is required, and in such cases ordinary tables are not suited to the case.

649. From the circumstance of the characteristic being known at a glance, the tables never give it, but are restricted to the seven figures of the decimal fractions. There are tables wherein the logarithms of all numbers from 1 to 100000 and even those of greater numbers are given, by means of small additional tables, showing what is to be added in proportion to the figures which the proposed numbers have more than those in the tables. But from what has been said, we think the use of them will not be difficult; and, supposing such tables before the reader, we propose the multiplication of the numbers 2401 and 343. The addition of the logarithms of these numbers will, from what has been shown, give the product, as follows:—

$$\left.\begin{array}{r}\text{L. } 343 = 2\cdot5352941\\ \text{L.}2401 = 3\cdot3803922\end{array}\right\}\text{added,}$$

$$\left.\begin{array}{r}\hline 5\cdot9156863\\ 6847\end{array}\right\}\text{subtracted,}$$

$$\begin{array}{r}\hline 16\end{array}$$

Hence the number sought is 823543. For the sum is the logarithm of the product required, and its characteristic 5 exhibits a product composed of 6 figures, and they are found, by the decimal product and the fraction, to be 823543.

650. But it is in the extraction of roots that logarithms are most serviceable; for example, if we have to extract the square root of 10, we have only to divide the logarithm of 10, which is 1·0000000, by 2, the quotient 0·5000000 is the logarithm of the root required, which, in the tables, answers so nearly to 3·16228, whose square answers to 10 so nearly, that it is only one hundred thousandth part too great.

651. The operation, in addition, of expressions consisting of several terms is frequently represented merely by signs, each expression being placed between two parentheses and connected with the rest by means of the sign $+$. Thus, to add the expressions $a+b+c$ and $d+e+f$ the sum is thus represented:—

$$(a+b+c)+(d+e+f).$$

This, however, is rather representing than performing addition; but, if the parentheses are left out it is then actually performed; for, as the number $d+e+f$ is to be added to the other, it is to be done by joining to it $+d$, then $+e$, and then $+f$. If any term is affected by the sign $-$, it must be joined in the proper way with that sign. To illustrate this, let us consider an example in pure numbers; for example, $16-9$ to $13-5$. If we begin by adding 16, we shall have $13-5+16$. But this was adding too much, since what was to be added was $16-9$, and it is therefore clear that we have added too much by 9; we must, therefore, take away the 9 by writing it with the negative sign, and thus we shall have the true sum—

$$13-5+16-9,$$

which shows that the sums result from writing all the terms each with its proper sign.

652. If, therefore, it were required to add the expression $d-e-f$ to $a-b+c$, the sum must be expressed as under:—

$$a-b+c+d-e-f;$$

wherein it is of no importance in what order we write the terms, if their proper signs be preserved; the sum, for example, might be written

$$c-e+a-f+d-b.$$

Hence it will be seen that addition is attended with no difficulty, be the forms of the terms to be added together what they may. Thus, suppose we wished to add the expressions $2a^3+6\sqrt{b}-4\text{L}.c$, and $5\sqrt{a}-7c$, they would be written

$$2a^3 + 6\sqrt{b} - 4\mathrm{L}.c + 5\sqrt{a} - 7c,$$

or in any other order, provided the proper signs are retained.

653. But it is often possible to abridge the representation of these, as when two or more terms destroy each other; thus, if in the same sum are found the terms $+a-a$, or $3a-4a+a$, or when two or more terms may be reduced to one: thus, —

$$\begin{array}{l} 3a+2a=5a;\ 7b-3b=+4b; \\ -6c+10c=+4c; \\ 5a-8a=-3a;\ \ -7+b=-6b; \\ -3c-4c=-7c; \\ 2a-5a+a=-2a;\ \ -3b-5b+2b=-6b. \end{array}$$

If, therefore, two or more terms are the same with regard to letters, their sum may be abridged; but such cases must not be confounded with such as $2aa+3a$ or $2b^3-b^4$, which cannot be abridged.

654. By considering some more examples of reduction, we shall be led to the discovery of an important point, — namely, that if we add together the sum of two numbers $a+b$ and their difference $a-b$, we obtain twice the greater of those two numbers. For, in adding $a+b$ and $a-b$, our rule gives $a+b+a-b$. Now $a+a=2a$ and $b-b=0$; the sum, therefore, is $2a$. We here subjoin two examples: —

$$\begin{array}{rl} & 3a-2b-c \\ & 5b-6c+a \\ \hline \text{Sum}\ .\ . & 4a+3b-7c \end{array} \qquad\qquad \begin{array}{rl} & a^3-2aab+2abb \\ & -aab+2abb+b^3 \\ \hline \text{Sum}\ .\ . & a^3-3aab+4abb-b^3 \end{array}$$

THE SUBTRACTION OF COMPOUND QUANTITIES.

655. To represent subtraction each expression is inclosed within two parentheses joining, by the sign $-$, the expression to be subtracted to that from which it is to be subtracted. Thus, if $d-e+f$ is to be subtracted from $a-b+c$, the remainder is written thus: —

$$(a-b+c)-(d-c+f);$$

and this method sufficiently shows which of the two expressions is to be subtracted from the other.

656. But if actual subtraction is to be performed, we must observe, first, that when we subtract a positive quantity $+b$ from another quantity $+a$, we obtain $a-b$; and, secondly, when we subtract a negative quantity $-b$ from a, we obtain $a+b$; for, to discharge the debt of a person is the same as to give him something. Suppose the expression $b-d$ is to be subtracted from the expression $a-c$, we must first take away b, which gives $a-c-b$. We have, however, taken away too much by the quantity d. Since we had to subtract only $b-d$, restoring, then, the value of d, we shall have

$$a-c-b+d:$$

from which it is evident that the terms of the expression to be subtracted must change their signs, and with such contrary signs be joined to the terms of the other expressions.

657. It is therefore, by means of this rule, easy to perform subtraction; for it is only necessary to write the expression from which we are to subtract, and join the other to it, without any change but that of the signs. Thus, in the first example, where it was required to subtract the expression $d-e+f$ from $a-b+c$, we obtain $a-b+c-d+e-f$. This will be rendered quite clear by an example in numbers. If, for example, we subtract $5-3+6$ from $7-2+3$, we obtain

$$7-2+3-5+3-6;$$

for $7-2+3=8$, also $5-3+6=8$, now $8-8=0$.

658. Subtraction being then thus easily performed, we have only to observe that if, in the remainder, two or more terms are found entirely similar with regard to the letters, the remainder may be reduced to an abridged form by the rules for a similar purpose given in addition. Suppose we have to subtract from $a+b$ or the sum of two quantities their difference, or $a-b$, we shall have $a+b-a+b$: now $a-a=0$ and $b+b=2b$; the remainder is therefore $2b$, that is to say, double the least of the quantities. The following examples will further illustrate what we have said: —

$$\begin{array}{c} aa+ab+bb \\ bb+ab-aa \\ \hline +2aa \end{array} \qquad \begin{array}{c} 3a-4b+5c \\ 2b+4c-6a \\ \hline 9a-6b+c \end{array} \qquad \begin{array}{c} a^3+3aab+3abb+b^3 \\ a^3-3aab+3abb-b^3 \\ \hline 6aab+2b^3 \end{array} \qquad \begin{array}{c} \sqrt{a}+2\sqrt{b} \\ \sqrt{a}-3\sqrt{b} \\ \hline +5\sqrt{b} \end{array}$$

THE MULTIPLICATION OF COMPOUND QUANTITIES.

659. Merely to represent compound quantities, each of the expressions to be multiplied together is placed within parentheses, and they are then to be joined together either with

or without the sign × between them. Thus, to represent the product of the two expressions $a-b+c$ and $d-e+f$ when multiplied together, we write

$$(a-b+c)\times(d-e+f);$$

and this mode of expressing products is much used, because it shows the factors whereof they are composed. To show, however, how any multiplication is to be actually conducted, let us take for example such a quantity as $a-b+c$ to be multiplied by 2; here each term is separately multiplied by that number, so that for the product we have

$$2a-2b+2c;$$

and the same takes place with all other numbers. Suppose, for example, d had been the number by which we had been required to multiply,

$$ad-bd+cd$$

would have been the product obtained.

660. We have here supposed that d was a positive number, but had the factor been negative, as $-e$, the rule formerly given must have been applied, namely, that unlike signs multiplied together produce −, and like signs produce +. We should therefore have had

$$-ae+be-ce.$$

661. To show the mode of multiplying a quantity A by a compound quantity $d-e$, it will be convenient to take for example one in common numbers: let A, for instance, be multiplied by $7-3$. Here it is manifest we have to take 4A; for if we first take A seven times, it will be necessary to subtract 3A from that product. In general, therefore, if we have to multiply by $d-e$, A must be first multiplied by d and then by e, and the last product must be subtracted from the first, whence we shall have $A-eA$. Suppose $A=a-b$, and that this quantity is to be multiplied by $d-e$, we shall have

$$\begin{array}{ll} & dA=ad-bd \\ & eA=ae-be \\ \hline \text{The product required} & =ad-bd-ae+be. \end{array}$$

Since, then, we know without doubt the product $(a-b)\times(d-e)$, we may now give the same example of multiplication under a different form; thus

$$\begin{array}{l} a-b \\ d-e \\ \hline ad-bd-ae+be; \end{array}$$

from which we learn that each term of the upper expression must be multiplied by each term of the lower; and that, with regard to the signs, the rule often before given must be strictly observed. From what has been said, we presume no difficulty will arise in calculating the following example, namely, to multiply $a+b$ by $a-b$.

$$\begin{array}{rl} & a+b \\ & a-b \\ \hline & aa+ab \\ & \quad\;\, -ab-bb \\ \hline \text{Product} & =aa-bb \end{array}$$

For a and b any determinate numbers may be substituted, so that out of the above examples arises the following theorem; viz. the product of the sum of two numbers multiplied by their difference is equal to the difference of the squares of those numbers; which may be thus expressed —

$$(a+b)\times(a-b)=aa-bb$$

From this last follows another theorem; namely, the difference of two square numbers is always a product, and divisible both by the sum and the difference of the roots of those two squares, consequently the difference of two squares can never be a prime number. We will now present to the reader some other examples: —

$$\text{(I.)}\quad \begin{array}{l} 2a-3 \\ \;\; a+2 \\ \hline 2aa-3a \\ \qquad +4-6 \\ \hline 2aa+\;-6 \\ \hline \end{array} \qquad \text{(II.)}\quad \begin{array}{l} 4aa-6a+9 \\ 2a+3 \\ \hline 8a^3-12aa+18a \\ \qquad -12aa-18a+27 \\ \hline 8a^3+27 \\ \hline \end{array} \qquad \text{(III.)}\quad \begin{array}{l} 3aa-2ab-bb \\ 2a-4b \\ \hline 6a^3-4aab-2abb \\ \qquad -12aab+8abb+4b^3 \\ \hline 6a^3-16aab+6abb+4b^3 \\ \hline \end{array}$$

$$\text{(IV.)}\quad \begin{array}{l} aa+2ab+2bb \\ aa-2ab+2bb \\ \hline a^4+2a^3b+2aabb \\ \qquad -2a^3b-4aabb-4ab^3 \\ \qquad\qquad +2aabb+4ab^3+4b^4 \\ \hline a^4+4b^4 \\ \hline \end{array} \qquad \text{(V.)}\quad \begin{array}{l} 2aa-3ab-4bb \\ 3aa-2ab+bb \\ \hline 6a^4-9a^3b-12aabb \\ \qquad -4a^3b+6aabb+8ab^3 \\ \qquad\qquad +2aabb-3ab^3-4b^4 \\ \hline 6a^4-13a^3b-4aabb+5ab^3-4b^4 \\ \hline \end{array}$$

$$\text{(VI.)}\quad \begin{array}{l} aa+bb+cc-ab-ac-bc \\ a+b+c \\ \hline a^3+abb+acc-aab-aac-abc \\ \quad +aab+b^3+bcc-abb-abc-bbc \\ \qquad\quad +aac+bbc+c^3-abc-acc-bcc \\ \hline a^3-3abc+b^3+c^3 \\ \hline \end{array}$$

When more than two quantities are to be multiplied together, it will be obvious that, having multiplied two of them together, their product must be multiplied by one of the remaining ones, and so on. The order in which they are multiplied is a matter of no importance. Thus, suppose in common numbers the four following factors: —

(I.)	(II.)	(III.)	(IV.)
$(1+2)$	$(1+2+4)$	$(2-1)$	$(2+1+4)$

Multiplying the factors I. and II., we have $3\times 7=21$. From factors III. and IV. we have $1\times 7=7$. Now, multiplying the product of I. and II. by the second product of III. and IV., we have $21\times 7=147$. Let us now change the order by multiplying first I. and III. together, and then II. and IV. The first product will be that of $3\times 1=3$, the second that of $7\times 7=49$. Then $3\times 49=147$, as in the first operation: and the same result will be produced in whatever order they are multiplied.

THE DIVISION OF COMPOUND QUANTITIES.

662. To represent division, we either use the ordinary mark of fractions, which is to separate by a line the dividend or numerator from the divisor or denominator: thus, to divide $a+b$ by $c+d$, the quotient is thus represented $\frac{a+b}{c+d}$; or, the two quantities being enclosed within parentheses, we place two points between the divisor and the dividend: thus, $(a+b):(c+d)$. Each of these expressions is read $a+b$ *divided by* $c+d$.

663. If it be required to divide a compound quantity by a simple one, each term must be divided separately. Thus, $10a-6b+8c$ divided by 2 gives $5a-3b+4c$; and $(aa-4ab):(a)$ gives $a-4b$. So, also, $(a^3-2aab+3abb):(a)=aa-2ab+3bb$; $(4aab-6aac+8abc):(2a)=2ab-3ac+4bc$; $(9aabc-12abbc+15abcc):(3abc)=3a-4b+5c$, &c.

664. If a term in the dividend is not divisible by the divisor, the quotient is represented by a fraction, as in the division of $a+b$ by a the quotient is $1+\frac{b}{a}$; so also,

$$(aa-ab+bb):(aa)=1-\frac{b}{a}+\frac{bb}{aa}.$$

Likewise, if we divide $2a+b$ by 2, we obtain the quotient of $a+\frac{b}{2}$; and here we must observe, that, instead of $\frac{b}{2}$ we may write $\frac{1}{2}b$, because $\frac{1}{2}$ times b is equal to $\frac{b}{2}$. And, similarly, $\frac{b}{3}$ is the same as $\frac{1}{3}b$, and $\frac{2b}{3}$ the same as $\frac{2}{3}b$, &c.

665. When the divisor is a compound quantity, division is not so easily performed; and when it cannot be so performed, we can do no more than represent the quotient by a fraction in the manner already described. We will, however, begin with some examples in which actual division will succeed. Suppose we have to divide $ac-bc$ by $a-b$: the quotient must, of course, be such that, when multiplied by the divisor $a-b$, it will produce the dividend $ac-bc$. Now, this quotient must contain c, for, without it, we could not obtain ac. In order, then, to try whether c is the whole quotient, we have only to multiply it by the divisor. Now, in the present case, if we multiply $a-b$ by c, we have $ac-bc$, which is the exact dividend, so that c is the whole quotient. It is equally clear that $(aa+ab):(a+b)=a$; $(3aa-2ab):(3a-2b)=a$; $(6aa-9ab):(2a-3b)=3a$, &c. Thus, then, we cannot fail to find a part of the quotient; and if what we have found when multiplied by the divisor does not exhaust the dividend, we have only to divide the remainder by the divisor, to obtain a second part of the quotient; and so proceed till we have found the whole of it.

666. Let us, as an example, divide $aa+3ab+2bb$ by $a+b$. In the first place, it is clear that the quotient will contain a, for without that term we could not obtain aa. Multiply-

ing, then, the divisor $a+b$ by a, we have $aa+ab$, which quantity subtracted from the dividend leaves the remainder $2ab+2bb$. Dividing this by $a+b$, it is evident the quotient must contain the term $2b$. Now, $2b$ multiplied by $a+b$ produces exactly $2ab+2bb$, and therefore $a+2b$ is the quotient required, which, multiplied by the divisor $a+b$, ought to produce the dividend $aa+3ab+2bb$. Below, the operation will be seen more strikingly.

$$\begin{array}{r} a+b)\,aa+3ab+2bb\,(a+2b \\ aa+ab \\ \hline 2ab+2bb \\ 2ab+2bb \\ \hline 0 \end{array}$$

The operation is facilitated by choosing one of the terms of the divisor to be written first, and then, in arranging the terms of the dividend, begin with the highest powers of the first term of the divisor. This term was a in the preceding example; and in the following examples it will be seen that the system is followed.

(I.) $$\begin{array}{r} a-b)\,a^3-3aab+3abb-b^3\,(aa-2ab+bb \\ a^3-aab \\ \hline -2aab+3abb \\ -2aab+2abb \\ \hline abb-b^3 \\ abb-b^3 \\ \hline 0 \end{array}$$

(II.) $$\begin{array}{r} a+b)\,aa-bb\,(a-b \\ aa+ab \\ \hline -ab-bb \\ -ab-bb \\ \hline 0 \end{array}$$

(III.) $$\begin{array}{r} 3a-2b)\,18aa-8bb\,(6a+4b \\ 18aa-12ab \\ \hline 12ab-8bb \\ 12ab-8bb \\ \hline 0 \end{array}$$

(IV.) $$\begin{array}{r} a+b)\,a^3+b^3\,(aa-ab+bb \\ a^3+aab \\ \hline -aab+b^3 \\ -aab-abb \\ \hline +abb+b^3 \\ +abb+b^3 \\ \hline 0 \end{array}$$

(V.) $$\begin{array}{r} 2a-b)\,8a^3-b^3\,(4aa+2ab+bb \\ 8a^3-4aab \\ \hline 4aab-b^3 \\ 4aab-2abb \\ \hline 2abb-b^3 \\ 2abb-b^3 \\ \hline 0 \end{array}$$

(VI.) $$\begin{array}{r} aa-2ab+bb)\,a^4-4a^3b+6aabb-4ab^3+b^4\,(aa-2ab+bb \\ a^4-2a^3b+aabb \\ \hline -2a^3b+5aabb-4ab^3 \\ -2a^3b+4aabb-2ab^3 \\ \hline aabb-2ab^3+b^4 \\ aabb-2ab^3+b^4 \\ \hline 0 \end{array}$$

(VII.) $$\begin{array}{r} aa-2ab+4bb)\,a^4+4aabb+16b^4\,(aa+2ab+4bb \\ a^4-2a^3b+4aabb \\ \hline 2a^3b+16b^4 \\ 2a^3b-4aabb+8ab^3 \\ \hline 4aabb-8ab^3+16b^4 \\ 4aabb-8ab^3+16b^4 \\ \hline 0 \end{array}$$

(VIII.)
$$\begin{array}{l}
aa-2ab+2bb)\,a^4+4b^4\,(aa+2ab+2bb \\
\qquad\qquad\quad a^4-2a^3b+2aabb \\ \hline
\qquad\qquad\qquad 2a^3b-2aabb+4b^4 \\
\qquad\qquad\qquad 2a^3b-4aabb+4ab^3 \\ \hline
\qquad\qquad\qquad\qquad 2aabb-4ab^3+4b^4 \\
\qquad\qquad\qquad\qquad 2aabb-4ab^3+4b^4 \\ \hline
\qquad\qquad\qquad\qquad\qquad 0
\end{array}$$

(IX.)
$$\begin{array}{l}
1-2x+xx)\,1-5x+10xx-10x^3+5x^4-x^5\,(1-3x+3xx-x^3 \\
\qquad\qquad 1-2x+\;\;xx \\ \hline
\qquad\qquad -3x+9xx-10x^3 \\
\qquad\qquad -3x+6xx-3x^3 \\ \hline
\qquad\qquad\qquad 3xx-7x^3+5x^4 \\
\qquad\qquad\qquad 3xx-6x^3+3x^4 \\ \hline
\qquad\qquad\qquad\quad -x^3+2x^4-x^5 \\
\qquad\qquad\qquad\quad -x^3+2x^4-x^5 \\ \hline
\qquad\qquad\qquad\qquad 0
\end{array}$$

THE RESOLUTION OF FRACTIONS INTO INFINITE SERIES.

667. We have already said that when the dividend is not divisible by the divisor, the quotient is expressed by a fraction. Thus, if we have to divide 1 by $1-a$, we obtain the fraction $1-\frac{1}{a}$. We may, however, attempt the division and continue it at pleasure according to the rules given, and, though under other forms, the true quotient will be found. Thus —

(I.)
$$\begin{array}{l}
1-a)\,1\quad(1+\frac{a}{1-a} \\
\qquad 1-a \\ \hline
\text{remainder } a
\end{array}$$

(II.) or
$$\begin{array}{l}
1-a)\,1\quad(1+a+\frac{aa}{1-a} \\
\qquad 1-a \\ \hline
\qquad\quad a \\
\qquad a-aa \\ \hline
\text{remainder } aa
\end{array}$$

To find a greater number of forms we need only continue dividing aa by $1-a$.

(III.)
$$\begin{array}{l}
1-a)\,aa\quad(aa+\frac{a^3}{1-a} \\
\qquad aa-a^3 \\ \hline
\qquad\quad a^3
\end{array}$$

(IV.) then
$$\begin{array}{l}
1-a)\,a^3\quad(a^3+\frac{a^4}{1-a} \\
\qquad a^3+a^4 \\ \hline
\qquad\quad a^4
\end{array}$$

(V.) and, again,
$$\begin{array}{l}
1-a)\,a^4\quad(a^4+\frac{a^5}{1-a} \\
\qquad a^4-a^5 \\ \hline
\qquad\quad a^5
\end{array}$$

All which shows that the fraction is equally represented under the following forms: (I.) $1+\frac{1}{1-a}$; (II.) $1+a+\frac{aa}{1-a}$; (III.) $1+a+aa+\frac{a^3}{1-a}$; (IV.) $1+a+aa+a^3+\frac{a^4}{1-a}$; (V.) $1+a+aa+a^3+a^4+\frac{a^5}{1-a}$, &c. Now, considering the first of these expressions, which is $1+\frac{a}{1-a}$, and remembering that 1 is the same as $\frac{1-a}{1-a}$, we have

$$1+\frac{a}{1-a}=\frac{1-a}{1-a}+\frac{a}{1-a}=\frac{1-a+a}{1-a}=\frac{1}{1-a};$$

and following the same process with respect to the second expression, $1+a+\frac{aa}{1-a}$, that is, if we reduce the integer part $1+a$ to the same denominator $1-a$, we have $\frac{1-aa}{1-a}$, to which if $+\frac{aa}{1-a}$ be added, we shall have $\frac{1-aa+aa}{1-a}$, that is $\frac{1}{1-a}$.

668. In the third expression, $1+a+aa+\frac{a^3}{1-a}$ the integer reduced to the denominator $1-a$ make $\frac{1-a^3}{1-a}$, and if to that be added the fraction $\frac{a^3}{1-a}$ we have $\frac{1}{1-a}$; whence all these expressions are equal in value to $\frac{1}{1-a}$, the proposed fraction. Hence, without the trouble of further division, we may continue the series to any extent, for we shall have $\frac{1}{1-a}=1+a+aa+a^3+a^4+a^5+a^6+a^7+\frac{a^8}{1-a}$; it may, indeed, be continued without end. On

this account it may be said that the proposed fraction has been resolved into an infinite series; and we arrive at the same time at the conclusion, that the value of this infinite series is the same as that of the fraction $\frac{1}{1-a}$. However astonishing this may seem, upon the consideration of some particular cases, it will be easily understood. Let us suppose that $a=1$. The series will then become $1+1+1+1+1+1+1$, &c., and the fraction $\frac{1}{1-1}$, to which it must be equal, become $\frac{1}{0}$, which, we have before seen, is a number infinitely great, and herein it is satisfactorily confirmed. If a be equal to 2, the series becomes $=1+2+4+8+16+32+64$, &c. to infinity, and its value must be $\frac{1}{1-2}$, that is to say $\frac{1}{-1}=-1$, which will perhaps appear absurd, until it is recollected that if we want to stop at any term of the series we must join the fraction which remains. Thus, if we stop at 64, after having written $1+2+4+8+16+32+64$, we must join the fraction $\frac{128}{1-2}$, or $\frac{128}{-1}$, or -128; we should therefore have $127-128$, which is -1.

669. These properties must be therefore considered when for a numbers greater than unity are assumed. But when a is less than 1 the whole becomes more intelligible. Thus, let $a=\frac{1}{2}$, we then have $\frac{1}{1-a}=\frac{1}{1-\frac{1}{2}}=\frac{1}{\frac{1}{2}}=2$, which will be equal to the following series, $1+\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\frac{1}{32}+\frac{1}{64}+\frac{1}{128}$, &c. to infinity. Now, taking only two terms of this series, we have $1+\frac{1}{2}$, and it wants $\frac{1}{2}$ that it may be equal to $\frac{1}{1-a}=2$. Take three terms, and it will want $\frac{1}{4}$, for the sum is then $1\frac{3}{4}$. Taking four terms, we have $1\frac{7}{8}$, and the deficiency is only $\frac{1}{8}$. Hence it is evident the more terms taken the less the difference becomes, and that if we continued on to infinity no difference would exist between the sum of the series and 2, the value of the fraction $\frac{1}{1-a}$.

670. Let $a=\frac{1}{3}$; the fraction $\frac{1}{1-a}$ will be $=\frac{1}{1-\frac{1}{3}}=\frac{3}{2}=1\frac{1}{2}$, which, reduced to an infinite series, becomes $1+\frac{1}{3}+\frac{1}{9}+\frac{1}{27}+\frac{1}{81}+\frac{1}{243}$, &c., and to which $\frac{1}{1-a}$ is consequently equal. Taking two terms, we have $1\frac{1}{3}$, $\frac{1}{6}$ being still wanting. If three terms are taken, we have $1\frac{4}{9}$, and $\frac{1}{18}$ will still be wanting. Four terms give us $1\frac{13}{27}$, and the difference is $\frac{1}{54}$. Since, then, the error continually becomes three times less, it will vanish at last.

671. Let $a=\frac{2}{3}$; we shall have $\frac{1}{1-a}=\frac{1}{1-\frac{2}{3}}=3$, and the series is $1+\frac{2}{3}+\frac{4}{9}+\frac{8}{27}+\frac{16}{81}+\frac{32}{243}$, &c. Taking $1\frac{2}{3}$, the error is $1\frac{1}{3}$; if we take three terms, which are equal to $2\frac{1}{9}$, the error is $\frac{8}{9}$; with four terms, or $2\frac{11}{27}$, the error is $\frac{16}{27}$.

672. If $a=\frac{1}{4}$, the fraction is $\frac{1}{1-\frac{1}{4}}=\frac{1}{\frac{3}{4}}=1\frac{1}{3}$, and the series is $1+\frac{1}{4}+\frac{1}{16}+\frac{1}{64}+\frac{1}{256}$, &c. The two first terms $=1+\frac{1}{4}$ give $\frac{1}{12}$ for the error, and if we take one term more we have $1\frac{5}{16}$, or an error of only $\frac{1}{48}$.

673. In the same manner, the fraction $\frac{1}{1+a}$ may be resolved into an infinite series by an actual division of the numerator 1 by the denominator $1+a$, as follows: —

$$\begin{array}{llllll}
1+a)1 & (1-a+aa-a^3+a^4 & & & & \\
\quad 1+a & & & & & \\
\hline
 & -a & & & & \\
 & -a-aa & & & & \\
\hline
 & & aa & & & \\
 & & aa+a^3 & & & \\
\hline
 & & & -a^3 & & \\
 & & & -a^3-a^4 & & \\
\hline
 & & & & a^4 & \\
 & & & & a^4+a^5 & \\
\hline
 & & & & & -a^5, \&c.
\end{array}$$

So that the fraction $\frac{1}{1+a}$ is equal to the series $1-a+aa-a^3+a^4-a^5+a^6-a^7$, &c.

674. If $a=1$, we have the following singular result: $\frac{1}{1+a}=\frac{1}{2}=1-1+1-1+1-1+1-1$, &c. to infinity. The result appears contradictory, because, if we stop at -1, the series gives 0, and if we finish by $+1$, it gives 1. This, however, solves the difficulty, for as we must neither stop at -1 nor $+1$, the sum can neither be 0 nor 1, but some quantity lying between these two, and therefore $=\frac{1}{2}$.

675. If we make $a=\frac{1}{2}$, the fraction will be $\frac{1}{1+\frac{1}{2}}=\frac{2}{3}$, which, consequently, expresses the value of the series, $1-\frac{1}{2}+\frac{1}{4}-\frac{1}{8}+\frac{1}{16}-\frac{1}{32}+\frac{1}{64}$, &c. to infinity. If we take only the two leading terms of this series, we have $\frac{1}{2}$, which is too small by $\frac{1}{6}$. If three terms be taken, we

have $\frac{3}{4}$, which is too much by $\frac{1}{12}$. Of four terms, we have $\frac{5}{8}$, which is too small by $\frac{1}{24}$, &c. If $a=\frac{1}{3}$, the fraction will be $\frac{1}{1+\frac{1}{3}}=\frac{3}{4}$, to which is equal the series $1-\frac{1}{3}+\frac{1}{9}-\frac{1}{27}+\frac{1}{81}-\frac{1}{243}+\frac{1}{729}$, &c. continued to infinity. Taking only two terms, we have $\frac{2}{3}$, which is too small by $\frac{1}{12}$: three terms are equal to $\frac{7}{9}$, which is too much by $\frac{1}{36}$. Four terms are equal to $\frac{20}{27}$, which is too small by $\frac{1}{108}$, and so on.

676. The fraction $\frac{1}{1+a}$ may be resolved by another method into an infinite series, namely, by dividing 1 by $a+1$, thus: —

$$
\begin{array}{l}
a+1)\,1\quad \left(\frac{1}{a}-\frac{1}{aa}+\frac{1}{a^3}-\frac{1}{a^4}+\frac{1}{a^5}\right. \\
\quad 1+\frac{1}{a} \\
\hline
\quad -\frac{1}{a} \\
\quad -\frac{1}{a}-\frac{1}{aa} \\
\hline
\qquad \frac{1}{aa} \\
\qquad \frac{1}{aa}+\frac{1}{a^3} \\
\hline
\qquad\quad -\frac{1}{a^3} \\
\qquad\quad -\frac{1}{a^3}+\frac{1}{a^4} \\
\hline
\qquad\qquad \frac{1}{a^4} \\
\qquad\qquad \frac{1}{a^4}+\frac{1}{a^5} \\
\hline
\qquad\qquad\quad -\frac{1}{a^5},\ \&c.
\end{array}
$$

Thus we find also that the fraction $\frac{1}{a+1}$ is equal to the infinite series $\frac{1}{a}-\frac{1}{aa}+\frac{1}{a^3}-\frac{1}{a^4}+\frac{1}{a^5}-\frac{1}{a^6}$, &c. If, then, we make $a=1$, we shall have the series $1-1+1-1+1-1$, &c. $=\frac{1}{2}$, as before; and if $a=2$, we shall have the series $\frac{1}{2}-\frac{1}{4}+\frac{1}{8}-\frac{1}{16}+\frac{1}{32}-\frac{1}{64}$, &c. $=\frac{1}{3}$.

677. So, generally, by resolving the general fraction $\frac{c}{a+b}$ into an infinite series, we have

$$
\begin{array}{l}
a+b)\,c\quad \left(\frac{c}{a}-\frac{bc}{aa}+\frac{bbc}{a^3}-\frac{b^3c}{a^4}\right. \\
\quad c+\frac{bc}{a} \\
\hline
\quad -\frac{bc}{a} \\
\quad -\frac{bc}{a}-\frac{bbc}{aa} \\
\hline
\qquad \frac{bbc}{aa} \\
\qquad \frac{bbc}{aa}+\frac{bbbc}{a^3} \\
\hline
\qquad\quad -\frac{b^3c}{a^3} \\
\qquad\quad -\frac{b^3c}{a^3}-\frac{b^4c}{a^4} \\
\hline
\qquad\qquad \frac{b^4c}{a^4}
\end{array}
$$

From which it appears that we may compare $\frac{c}{a+b}$ with the series $\frac{c}{a}-\frac{bc}{aa}+\frac{bbc}{a^3}-\frac{b^3c}{a^4}$, &c. to infinity. Let $a=2$, $b=4$, $c=3$; we shall then have $\frac{c}{a+b}=\frac{3}{4+2}=\frac{3}{6}=\frac{1}{2}=\frac{3}{2}-3+6-12$, &c.

678. If $a=10$, $b=1$, and $c=11$, we have $\frac{c}{a+b}=\frac{11}{10+1}=1=\frac{11}{10}-\frac{11}{100}+\frac{11}{1000}-\frac{11}{10000}$, &c. Taking only one term of this series, we have $\frac{11}{10}$, which is too great by $\frac{1}{10}$; if we take two terms, we have $\frac{99}{100}$, which is too small by $\frac{1}{100}$; if three terms, $\frac{1001}{1000}$, which is too great by $\frac{1}{1000}$, &c. If the divisor contain more than two terms, the division may, in the same manner, still be continued to infinity. Thus, suppose the fraction $\frac{1}{1-a+aa}$ proposed; the infinite series to which it is equal would be found as follows: —

$$\begin{array}{ll}
1-a+aa)\,1 & (1+a-a^3-a^4+a^6+a^7,\ \&c.\\
\underline{1-a+aa} & \\
a-aa & \\
\underline{a-aa+a^3} & \\
-a^3 & \\
\underline{-a^3+a^4-a^5} & \\
-a^4+a^5 & \\
\underline{-a^4+a^5-a^6} & \\
a^6 & \\
\underline{a^6-a^7+a^8} & \\
a^7-a^8 & \\
\underline{a^7-a^8+a^9} & \\
-a^9 &
\end{array}$$

Hence we have the equation $\frac{1}{1-a+aa}=1+a-a^3-a^4+a^6+a^7-a^9-a^{10}$, &c.; in which, if we make $a=1$, we have $1=1+1-1-1+1+1-1-1+1+1$, &c., which series contains twice that of $1-1+1-1+1$, &c. found above; and as that has been found equal to $\frac{1}{2}$, it is to be expected that we should find $\frac{2}{2}$, or 1 for the value of that just determined. If $a=\frac{1}{2}$ we shall have the equation $\frac{1}{\frac{3}{4}}=\frac{4}{3}=1\frac{1}{2}-\frac{1}{8}-\frac{1}{16}+\frac{1}{64}-\frac{1}{128}+\frac{1}{512}$, &c. If $a=\frac{1}{3}$ we shall have the equation $\frac{1}{\frac{7}{9}}=\frac{9}{7}=1+\frac{1}{3}-\frac{1}{27}-\frac{1}{81}+\frac{1}{729}$, &c., of which series, if the four leading terms be taken, we have $\frac{104}{81}$, which is only $\frac{1}{567}$ less than $\frac{9}{7}$. Again, if $a=\frac{2}{3}$, we have $\frac{1}{\frac{7}{9}}=\frac{9}{7}=1+\frac{2}{3}-\frac{8}{27}-\frac{16}{81}+\frac{64}{729}$, &c., a series which is equal to the preceding one, and subtracting one from the other, $\frac{1}{3}-\frac{7}{27}-\frac{15}{81}+\frac{63}{729}$, &c. must $=0$. The four terms added together make $-\frac{2}{81}$.

679. The method of resolving generally all fractions into infinite series which has been above given, is often of great utility, and though it never ceases, an infinite series may have a determinate value. Many discoveries of the highest importance have been derived from this branch of mathematics, which, on that account, well deserves the study and comprehension of the reader.

THE SQUARES OF COMPOUND QUANTITIES.

680. To find the square of a compound quantity, it is only necessary to multiply by itself, and it is the square required; thus the square of $a+b$ is found in the following manner:—

$$\begin{array}{r}
a+b\\
\underline{a+b}\\
aa+ab\\
\underline{ab+bb}\\
aa+2ab+bb
\end{array}$$

From which we learn that the square of any number comprising two terms consists, first, of the squares of each term, namely aa and bb, and twice the product of the two terms, that is $2ab$. In figures, suppose $a=12$ and $b=4$, that is, let it be required to find the square of 16, we have $144+96+16$, or 256. This formula then gives us the power of finding the squares of numbers, however great, if we divide them into two parts. Thus, to find the square of 49, recollecting that this number is equal to $40+9$, its square is $=1600+720+81=2401$. From the same cause it is evident that the square of $a+1$ will be $aa+2a+1$; and since the square of a is aa, we find the square of $a+1$ by adding to it $2a+1$, wherein it is observable that this $2a+1$ is the sum of the two roots a and $a+1$. Hence, the square of 10 being 100, that of 11 will be $100+21$ (that is, $100+2\times10+1$). The square of 49 being 2401, that of 50 is $2401+99=2500$; the square of 50 being 2500, that of $51=2500+101=2601$, &c.

681. The square of a compound quantity, as $a+b$, is thus represented $(a+b)^2$. We have then $(a+b)^2=aa+2ab+bb$, whence result the following equations:—

$(a+1)^2=aa+2a+1$; $(a+2)^2=aa+4a+4$; $(a+3)^2=aa+6a+9$;
$(a+4)^2=aa+8a+16$, &c.

682. If the root is $a-b$, the square of it is $aa-2ab+bb$, which also contains the squares of the two terms, but in such a manner, that from their sum must be taken twice the product of those terms; thus, let $a=10$ and $b=-1$, the square of 9 will be found to be $100-20+1=81$.

683. Having then the equation $(a-b)^2=aa-2ab+bb$, we shall have $(a-1)^2=aa-2a+1$. From which it is evident that the square of $a-1$ is found by subtracting from aa the sum of the two roots a and $a-1$, that is, $2a-1$. Let $a=50$, then $aa=2500$; and $a-1=49$; hence $49^2=2500-99=2401$.

684. The rule is moreover confirmed and illustrated by fractions; for, taking as the root $\frac{3}{5}+\frac{2}{5}$ (which make 1), the square will be

$$\tfrac{9}{25}+\tfrac{4}{25}+\tfrac{12}{25}=\tfrac{25}{25}, \text{ that is, } 1.$$

And further, the square of $\frac{1}{2}-\frac{1}{3}$ (or of $\frac{1}{6}$) will be $\frac{1}{4}-\frac{1}{3}+\frac{1}{9}=\frac{1}{36}$.

685. If the root consists of a greater number of terms, the square is determined in a similar manner; take, for instance, the square of $a+b+c$.

$$\begin{array}{llllll}
a+b+c & & & & & \\
a+b+c & & & & & \\
\hline
aa+ab & +ac & & +bc & & \\
ab & +ac & +bb & +bc & +cc & \\
\hline
aa+2ab & +2ac & +bb & +2bc & +cc &
\end{array}$$

686. It will be perceived that the product includes the square of each term of the roots, and, besides that, the double products of those terms multiplied two by two. To exhibit this in figures, divide the number 345 into three parts, $300+40+5$; its square will then be composed of the following parts:—

$$\begin{array}{rcl}
90000 & = & 300^2 \\
1600 & = & 40^2 \\
25 & = & 5^2 \\
24000 & = & 2\times 300\times 40 \\
3000 & = & 2\times 300\times 5 \\
400 & = & 2\times 40\times 5 \\
\hline
119025 & &
\end{array}
\qquad\qquad
\begin{array}{r}
345 \\
345 \\
\hline
1725 \\
1380 \\
1035 \\
\hline
119025 \\
\hline
\end{array}$$

119025, which is equal to the product of 345×345.

687. Though some of the terms of the root be negative, the rule still holds good, only that we must be careful in prefixing the signs to the double products. For instance, the square of $a-b-c$ being $aa+bb+cc-2ab-2ac+2bc$, if the number 345 be represented by $400-50-5$, we shall have

$$\begin{array}{r}
\text{Positive parts.} \\
+160000 \\
2500 \\
500 \\
25 \\
\hline
+163025 \\
-\ \ 44000 \\
\hline
\end{array}
\qquad\qquad
\begin{array}{r}
\text{Negative parts.} \\
-40000 \\
4000 \\
\hline
-44000 \\
 \\
 \\
 \\

\end{array}$$

119025, the square of 345, as before.

EXTRACTION OF ROOTS OF COMPOUND QUANTITIES.

688. For the extraction of the roots of compound quantities, and the rule by which the operation is guided, we must consider with attention the square of the root $a+b$, which is $aa+2ab+bb$. It will be seen that it is composed of several terms; and that, therefore, the root will comprise more than one term, and that if the square be written so that the powers of one of the letters, as a, may continually diminish, the first term will be the first square of the root; and as, in the instance adduced, the first term of the square is aa, it is certain that the first term of the root is a. Having thus found the first term of the root, that is, a, we have to consider the rest of the square, namely $2ab+bb$, and endeavour to ascertain from it the second part of the root, which is b. Now as the remainder $2ab+bb$, which may be represented by the product $(2a+b)b$, has two factors, $2a+b$ and b, it is evident that the latter b, which is the second part of the root, will be found by dividing the remainder $2ab+bb$ by $2a+b$. The quotient then arising from the division of the above remainder by $2a+b$, is the second term of the root required. In the division, it is to be observed that $2a$ is the double of the first term a, which is already determined, and as the second term is yet unknown, though for the present its place must be left empty, the division may be attempted, since in it we attend only to the first term $2a$. When, however, the quotient is found, which is here b, it must be put in the empty place, by which the division is rendered complete. The operation is thus represented:—

$$\begin{array}{rl} & aa+2ab+bb\,(a+b \\ & aa \\ \hline 2a+b) & 2ab+bb \\ & 2ab+bb \\ \hline & 0 \end{array}$$

689. In a similar manner may be found the square root of other compound quantities, provided they are squares, as may be seen by the following examples.

$$\text{(I.)}\ \begin{array}{rl} & aa+6ab+9bb\,(a+3b \\ & aa \\ \hline 2a+3b) & 6ab+9bb \\ & 6ab+9bb \\ \hline & 0 \end{array} \qquad \text{(II.)}\ \begin{array}{rl} & 4aa-4ab+bb\,(2a-b \\ & 4aa \\ \hline 4a-b) & -4ab+bb \\ & -4ab+bb \\ \hline & 0 \end{array} \qquad \text{(III.)}\ \begin{array}{rl} & 9pp+24pq+16qq\,(3p+4q \\ & 9pp \\ \hline 6p+4q) & 24pq+16qq \\ & 24pq+16qq \\ \hline & 0 \end{array}$$

$$\text{(IV.)}\ \begin{array}{rl} & 25xx-60x+36\,(5x-6 \\ & 25xx \\ \hline 10x-6) & -60x+36 \\ & -60x+36 \\ \hline & 0 \end{array}$$

690. If a remainder occurs after division, it proves that the root is composed of more than two terms. In which case, the two terms already found are considered as forming the first part, and we must try to obtain the other from the remainder in the same manner as the second part of the root was found. The following examples will show the mode of operation.

$$\text{(I.)}\ \begin{array}{rl} & aa+2ab-2ac-2bc+bb+cc\,(a+b+c \\ & aa \\ \hline 2a+b) & 2ab-2ac-2bc+bb+cc \\ & 2ab \qquad\qquad\quad +bb \\ \hline 2a+2b-c) & -2ac-2bc+cc \\ & -2ac-2bc+cc \\ \hline & 0 \end{array} \qquad \text{(II.)}\ \begin{array}{rl} & a^4+2a^3+3aa+2a+1\,(aa+a+1 \\ & a^4 \\ \hline 2aa+a) & 2a^3+3aa \\ & 2a^3+\ aa \\ \hline 2aa+2a+1) & 2aa+2a+1 \\ & 2aa+2a+1 \\ \hline & 0 \end{array}$$

$$\text{(III.)}\ \begin{array}{rl} & a^6-6a^5b+15a^4bb-20a^3b^3+15aab^4-6ab^5+b^6\,(a^3-3aab+3abb-b^3 \\ & a^6 \\ \hline 2a^3-3aab) & -6a^5b+15a^4bb \\ & -6a^5b+\ 9a^4bb \\ \hline 2a^3-6aab+3abb) & 6a^4bb-20a^3b^3+15aab^4 \\ & 6a^4bb-18a^3b^3+\ 9aab^4 \\ \hline 2a^3-6aab+6abb-b3) & -2a^3b^3+\ 6aab^4-6ab^5+b^5 \\ & -2a^3b^3+\ 6aab^4-6ab^5+b^6 \\ \hline & 0 \end{array}$$

691. From this method of extracting the square root, it is easy to reduce the rule given for that purpose in common books of arithmetic; as in the following examples in numbers.

$$\begin{array}{rl} & \dot{5}2\dot{9}\,(23 \\ & 4 \\ \hline 43) & 129 \\ & 129 \\ \hline & 0 \end{array} \qquad \begin{array}{rl} & 9\dot{4}0\dot{9}\,(97 \\ & 81 \\ \hline 187) & 1309 \\ & 1309 \\ \hline & 0 \end{array} \qquad \begin{array}{rl} & \dot{1}5\dot{1}2\dot{9}\,(123 \\ & 1 \\ \hline 22) & 51 \\ & 44 \\ \hline 243) & 729 \\ & 729 \\ \hline & 0 \end{array} \qquad \begin{array}{rl} & \dot{1}5\dot{2}2\dot{7}5\dot{6}\,(1234 \\ & 1 \\ \hline 2{\cdot}2) & 52 \\ & 44 \\ \hline 243) & 827 \\ & 729 \\ \hline 2464) & 9856 \\ & 9856 \\ \hline & 0 \end{array}$$

692. If there be a remainder after the whole operation, it proves that the number is not an exact square, and therefore its root cannot be assigned. When this is the case, the radical sign before mentioned must be written before the quantity, and the quantity itself is placed between parentheses, or under a line. Thus, the square root of $aa+bb$ is represented by

$\sqrt{}(aa+bb)$, or by $\sqrt{aa+bb}$, and $\sqrt{}(1-xx)$ or $\sqrt{1-xx}$ expresses the square root of $1-xx$. Instead of the radical sign the fractional exponent $\frac{1}{2}$ may be used, thus $(aa+bb)^{\frac{1}{2}}$ to $\overline{aa+bb}^{\,\frac{1}{2}}$ equally represent the square root of $aa+bb$.

CALCULATION OF IRRATIONAL QUANTITIES.

693. The addition of two or more irrational quantities is performed by writing all the terms in succession, each with its proper sign. They may often be abbreviated thus: for $\sqrt{a}+\sqrt{a}$ we may write $2\sqrt{a}$, and $\sqrt{a}-\sqrt{a}=0$, because the terms destroy one another. Thus the quantities $3+\sqrt{2}$ and $1+\sqrt{2}$ added together, make $4+2\sqrt{2}$ or (590.) $4+\sqrt{8}$. The sum of $5+\sqrt{3}$ and $4-\sqrt{3}$ is 9, and that of $2\sqrt{3}+3\sqrt{2}$ and $\sqrt{3}-\sqrt{2}$ is $3\sqrt{3}+2\sqrt{2}$.

694. Subtraction is equally simple, since we have only to change the signs of the numbers to be subtracted, and then add them together, thus: —

$$\begin{array}{rl}
\text{Subtract from} & 4-\sqrt{2}+2\sqrt{3}-3\sqrt{5}+4\sqrt{6} \\
\text{The numbers} & 1+2\sqrt{2}-2\sqrt{3}-5\sqrt{5}+6\sqrt{4} \\
\hline
 & 3-3\sqrt{3}+4\sqrt{3}+2\sqrt{5}+2\sqrt{6}
\end{array}$$

695. In multiplication it must be remembered that $\sqrt{a}$ multiplied by $\sqrt{a}$ produces a, and that if the numbers which follow the sign $\sqrt{}$ are different, as a and b, we have $\sqrt{ab}$ for the product of $\sqrt{a}$ multiplied by $\sqrt{b}$. From due observance of this, the following examples are easily calculated.

$$\begin{array}{l}
1+\sqrt{2} \\
1+\sqrt{2} \\
\hline
1+\sqrt{2} \\
\quad+\sqrt{2}+2 \\
\hline
1+2\sqrt{2}+2=3+2\sqrt{2}
\end{array}
\qquad\qquad
\begin{array}{l}
4+2\sqrt{2} \\
2-\sqrt{2} \\
\hline
8+4\sqrt{2} \\
\quad-4\sqrt{2}-4 \\
\hline
8-4 = 4
\end{array}$$

The rules apply also to imaginary quantities, and it will only be necessary to mention that $\sqrt{-a}$ multiplied by $\sqrt{-a}$ produces $-a$.

696. To find the cube of $-1+\sqrt{-3}$, we take the square of that number, and multiply such square by the number, as follows: —

$$\begin{array}{l}
-1+\sqrt{-3} \\
-1+\sqrt{-3} \\
\hline
1-\sqrt{-3} \\
\quad-\sqrt{-3}-3 \\
\hline
1-2\sqrt{-3}-3=-2-2\sqrt{-3} \\
\qquad\qquad\qquad\quad -1+\sqrt{-3} \\
\hline
\qquad\qquad\qquad\quad 2+2\sqrt{-3} \\
\qquad\qquad\qquad\qquad -2\sqrt{-3}+6 \\
\hline
\qquad\qquad\qquad\quad 2+6 = 8
\end{array}$$

697. To divide surds, we have only to express the quantity in the form of a fraction, which may then be changed into another expression having a rational denominator. Thus, for instance, if the denominator be $a+\sqrt{b}$, and it as well as the numerator be multiplied by $a-\sqrt{b}$, the new denominator will be $aa-b$, in which no radical sign occurs. Let it, then, be required to divide $3+2\sqrt{2}$ by $1+\sqrt{2}$, we have $\frac{3+2\sqrt{2}}{1+\sqrt{2}}$. Multiplying both terms of the fraction by $1-\sqrt{2}$, we have for the numerator, —

$$\begin{array}{l}
3+2\sqrt{2} \\
1-\sqrt{2} \\
\hline
3+2\sqrt{2} \\
\quad-3\sqrt{2}-4 \\
\hline
3-\sqrt{2}-4=-\sqrt{2}-1;
\end{array}$$

and for the denominator, —

$$\begin{array}{l}
1+\sqrt{2} \\
1-\sqrt{2} \\
\hline
1+\sqrt{2} \\
\quad-\sqrt{2}-2 \\
\hline
1-2=-1.
\end{array}$$

The new fraction is therefore $\frac{-\sqrt{2}-1}{-1}$; and if the terms be again multiplied by -1, we shall have for the numerator $\sqrt{2}+1$, and $+1$ for the denominator. It is easy to show that $\sqrt{2}+1$ is equal to the proposed fraction $\frac{3+2\sqrt{2}}{1+\sqrt{2}}$; for $\sqrt{2}+1$ being multiplied by the divisor $1+\sqrt{2}$, thus —

$$\begin{array}{rl}
 & 1+\sqrt{2} \\
 & 1+\sqrt{2} \\
\cline{2-2}
 & 1+\sqrt{2} \\
 & \quad +\sqrt{2}+2 \\
\cline{2-2}
\text{we have} & 1+2\sqrt{2}+2=3+2\sqrt{2}.
\end{array}$$

698. Fractions may be transformed into others which have rational denominators. Thus, in the fraction $\frac{1}{5-2\sqrt{6}}$, by multiplying both numerator and denominator by $5+2\sqrt{6}$, it becomes $\frac{5+2\sqrt{6}}{1}=5+2\sqrt{6}$. When the denominator contains several terms, the radical signs may, in the same manner, be made to vanish one by one. Thus, in the fraction $\frac{1}{\sqrt{10}-\sqrt{2}-\sqrt{3}}$, the two terms may be multiplied by $\sqrt{10}+\sqrt{2}+\sqrt{3}$, by which is obtained the fraction $\frac{\sqrt{10}+\sqrt{2}+\sqrt{3}}{5-2\sqrt{6}}$. Then, multiplying its numerator and denominator by $5+2\sqrt{6}$, we have $5\sqrt{10}+11\sqrt{2}+9\sqrt{3}+2\sqrt{60}$.

OF CUBES, AND THE EXTRACTION OF THEIR ROOTS.

699. The cube of a root $a+b$ is found by multiplying its square $aa+2ab+bb$ again by $a+b$, thus: —

$$\begin{array}{l}
aa+2ab+bb \\
\quad a+b \\
\hline
a^3+2aab+\ abb \\
\qquad\quad aab+2abb+b^3 \\
\hline
a^3+3aab+3abb+b^3 = \text{to the cube of } a+b.
\end{array}$$

The cube, then, contains the cubes of the two parts of the root, and, besides that, $3aab+3abb$, a quantity equal to $(3ab)\times(a+b)$, that is, the triple product of the two parts a and b multiplied by their sum. From which we learn, that when a root is composed of two terms, its cube is easily found. Thus, the number $5=3+2$; its cube, therefore, is $27+8+18\times 5=125$.

700. When the cube, as $a^3+3aab+3abb+b^3$, is given to find the root, the following is the process, the cube being arranged according to the powers of one letter. By the first term a^3 we perceive that a, whose cube is a^3, is the first term of the root; if, then, that cube be subtracted from the cube proposed, the remainder, $3aab+3abb+b^3$, will furnish the second term of the root. Now, knowing that the second term is $+b$, our object is to find how it may be derived from the above remainder. This remainder may be expressed by two factors, — namely, $(3aa+3ab+bb)\times(b)$; if, therefore, we divide by the first of them, we obtain $+b$, the second part of the root required.

701. But the second term, as well as the divisor, are supposed to be unknown; we know, however, the first term of that divisor, — that is, $3aa$, or thrice the square of the first term, already found; and that is sufficient, for by that it is easy to find the other part b, and then complete the divisor before performing the division. For this purpose we must join to $3aa$ thrice the product of the two terms, or $3ab$ and bb, or the square of the second term of the root. We subjoin two examples: —

$$\begin{array}{rl}
\text{(I.)} & a^3+12aa+48a+64(a+4 \\
 & a^3 \\
\cline{2-2}
3aa+12a+16) & 12aa+48a+64 \\
 & 12aa+48a+64 \\
\cline{2-2}
 & \qquad 0
\end{array}$$

$$\begin{array}{rl}
\text{(II.)} & a^6-6a^5+15a^4-20a^3+15a^2-6a+1(aa-2a+1 \\
 & a^6 \\
\cline{2-2}
3a^4-6a^3+4aa) & -6a^5+15a^4-20a^3 \\
 & -6a^5+12a^4-\ 8a^3 \\
\cline{2-2}
3a^4-12a^3+12aa+3a^2-6a+1) & 3a^4-12a^3+15a^2-6a+1 \\
 & 3a^4-12a^3+15a^2-6a+1 \\
\cline{2-2}
 & \qquad 0
\end{array}$$

On this analysis is founded the common rule for the extraction in numbers of the cube root. Take, for example, the number 4096.

$$\begin{array}{lr|l}
\multicolumn{1}{l}{} & \multicolumn{1}{r}{} & \dot{4}09\dot{6}\,(10+6=16 \\
\multicolumn{1}{l}{} & \multicolumn{1}{r}{} & \underline{1000} \\
\text{3 times } 10^2 & =300 & 3096 \\
\text{3 times } 10\times 6 & =180 & \\
6^2\text{ (second term)} & =\underline{\ \ 36} & \\
 & 516 & \underline{3096} \\
 & & \ \ 0
\end{array}$$

We will further extract the cube root of 82881856.

$$\begin{array}{lr|l}
\multicolumn{1}{l}{} & \multicolumn{1}{r}{} & 8\dot{2}88\dot{1}85\dot{6}\,(400+30+6 \\
\multicolumn{1}{l}{} & \multicolumn{1}{r}{} & \underline{64000000} \\
\text{3 times } 400^2 \quad - \quad - & =480000 & 18881856 \\
\text{3 times } 400\times 30 \ - \quad - & =\ \ 36000 & \\
30^2\text{ (square of second term)} & =\underline{\qquad 900} & \\
 & 516900 & \underline{15502000} \\
\text{3 times } 430^2 \quad - \quad - & =554700 & 13374856 \\
\text{3 times } 430\times 6 \ - \quad - & =\ \ \ 7740 & \\
6^2\text{ (square of third term)} & =\underline{\qquad\ 36} & \\
 & \underline{562476} & \underline{13374856} \\
 & & \qquad 0
\end{array}$$

THE HIGHER POWERS OF COMPOUND QUANTITIES.

702. Powers of a greater number of degrees than squares and cubes are now to be considered. We have already explained the method in which they are represented by exponents. It will be found convenient to keep in mind that, in dealing with a compound root, it is inclosed in a parenthesis. For instance, $(a+b)^4$ signifies that $a+b$ is to be raised to the fourth power or degree, and that $(a-b)^7$ expresses the seventh power of $a-b$; the subject of this section is to explain the nature of these powers, in which some peculiarities will be noticed.

703. If the root or first power be $a+b$, all the higher powers will be found by multiplying the last power found again by the root, as in the following example: —

$$\begin{array}{rl}
(a+b)^1 = & a+b \\
 & \underline{a+b} \\
 & aa+ab \\
 & \quad +ab+bb \\ \cline{2-2}
(a+b)^2 = & aa+2ab+bb \\
 & \underline{a+b} \\
 & a^3+2aab+\ abb \\
 & \quad +\ aab+2abb+b^3 \\ \cline{2-2}
(a+b)^3 = & a^3+3aab+3abb+b^3 \\
 & \underline{a+b} \\
 & a^4+3a^3b+3aabb+\ ab^3 \\
 & \quad +\ a^3b+3aabb+3ab^3+b^4 \\ \cline{2-2}
(a+b)^4 = & a^4+4a^3b+6aabb+4ab^3+b^4 \\
 & \underline{a+b} \\
 & a^5+4a^4b+6a^3bb+4aab^3+\ ab^4 \\
 & \quad +\ a^4b+4a^3bb+6aab^3+4ab^4+b^5 \\ \cline{2-2}
(a+b)^5 = & a^5+5a^4b+10a^3bb+10aab^3+5ab^4+b^5 \\
 & \underline{a+b} \\
 & a^6+5a^5b+10a^4bb+10a^3b^3+\ 5a^2b^4+\ ab^5 \\
 & \quad +\ a^5b+\ 5a^4bb+10a^3b^3+10a^2b^4+5ab^5+b^6 \\ \cline{2-2}
(a+b)^6 = & a^6+6a^5b+15a^4bb+20a^3b^3+15a^2b^4+6ab^5+b^6,\ \&c.
\end{array}$$

704. In a similar manner are found the powers of the root $a-b$, the only difference being that the even or 2d, 4th, 6th, &c. terms will be found to be affected by the sign minus.

$$\begin{array}{ll}
(a-b)^1 = & a-b \\
& a-b \\ \cline{2-2}
& aa-ab \\
& \quad -ab+bb \\ \cline{2-2}
(a-b)^2 = & aa-2ab+bb \\
& a-b \\ \cline{2-2}
& a^3-2aab+\ abb \\
& \quad -\ aab+2abb-b^3 \\ \cline{2-2}
(a-b)^3 = & a^3-3aab+3abb-b^3 \\
& a-b \\ \cline{2-2}
& a^4-3a^3b+3aabb-\ ab^3 \\
& \quad -\ a^3b+3aabb-3ab^3+b^4 \\ \cline{2-2}
(a-b)^4 = & a^4-4a^3b+6aabb-4ab^3+b^4 \\
& a-b \\ \cline{2-2}
& a^5-4a^4b+6a^3bb-4aab^3+\ ab^4 \\
& \quad -\ a^4b+4a^3bb-6aab^3+4ab^4-b^5 \\ \cline{2-2}
(a-b)^5 = & a^5-5a^4b+10a^3bb-10aab^3+5ab^4-b^5 \\
& a-b \\ \cline{2-2}
& a^6-5a^5b+10a^4bb-10a^3b^3+\ 5aab^4-\ ab^5 \\
& \quad -\ a^5b+\ 5a^4bb-10a^3b^3+10aab^4-5ab^5+b^6 \\ \cline{2-2}
(a-b)^6 = & a^6-6a^5b+15a^4bb-20a^3b^3+15aab^4-6ab^5+b^6, \text{ \&c.}
\end{array}$$

705. In this last example all the odd powers of b have the sign $-$, while the even powers retain the sign $+$. The reason is, that the powers of that letter ascend in the following series, $-b$, $+bb$, $-b^3$, $+b^4$, $-b^5$, $+b^6$, &c., which sufficiently indicates that the even powers must be affected by the sign $+$, and the odd ones by the sign $-$. The labour of the calculation being considerable, it is important to find a mode of performing the operation in an abridged manner. Now, if in the powers above determined we take away the numbers, or *coefficients* preceding each term, we shall observe the following order: first, in each succeeding term the powers of a decrease by unity, whereas the powers of b increase in the same proportion, so that the sum of the exponents of a and b is always the same, and always equal to the power of the exponent required; and, lastly, we find the term b by itself raised to the same power. Hence we know that if the tenth power of b were required, the terms without their coefficients would stand in the following order: a^{10}, a^9b, a^8b^2, a^7b^3, a^6b^4, a^5b^5, a^4b^6, a^3b^7, a^2b^8, ab^9, b^{10}. To determine the coefficients or numbers by which these are to be multiplied, we may observe that, with regard to the first term, its coefficient is always unity; and that, in respect of the second, its coefficient is always the exponent of the power; but the order of the other coefficients is not so manifest, though there is a law by which they are governed, which the following table will show.

Powers.	Coefficients.	Sum of the coefficients.
I	1, 1	$2 = 2^1$
II	1, 2, 1	$4 = 2^2$
III	1, 3, 3, 1	$8 = 2^3$
IV	1, 4, 6, 4, 1	$16 = 2^4$
V	1, 5, 10, 10, 5, 1	$32 = 2^5$
VI	1, 6, 15, 20, 15, 6, 1	$64 = 2^6$
VII	1, 7, 21, 35, 35, 21, 7, 1	$128 = 2^7$
VIII	1, 8, 28, 56, 70, 56, 28, 8, 1	$256 = 2^8$
IX	1, 9, 36, 84, 126, 126, 84, 36, 9, 1	$512 = 2^9$
X	1, 10, 45, 120, 210, 252, 210, 120, 45, 10, 1	$1024 = 2^{10}$

From which we may see that the tenth power of $a+b$ will be $a^{10}+10a^9b+45a^8bb+120a^7b^3+210a^6b^4+252a^5b^5+210a^4b^6+120a^3b^7+45aab^8+10ab^9+b^{10}$.

706. The sum of the coefficients in each power is equal to the number 2 raised to the same power, as will be seen by reference to the above table, and they increase from the beginning to the middle, and then decrease in the same order. In the even powers the greatest coefficients are exactly in the middle, but in the odd powers two coefficients equal and greater than the others are found in the middle belonging to the mean terms. We shall hereafter touch upon the reason of the following rule for determining the coefficients

in all powers proposed. Let the power proposed be the seventh, then placing the exponent of the power as the numerator, and letting the denominator follow in the natural order of the numbers 1, 2, 3, 4, &c., we have the following fractions, $\frac{7}{1}$, $\frac{6}{2}$, $\frac{5}{3}$, $\frac{4}{4}$, $\frac{3}{5}$, $\frac{2}{6}$, $\frac{1}{7}$. Now, as the first coefficient is always 1, the first fraction gives the second coefficient, the product of the two first fractions multiplied together gives the third coefficient, the product of the three first fractions represents the fourth coefficient, and so on; thus, for instance, the fifth coefficient will be the product of $\frac{7}{1} \times \frac{6}{2} \times \frac{5}{3} \times \frac{4}{4} = 35$, &c. This rule renders it unnecessary to find the preceding coefficients, and enables us to discover immediately the coefficients which belong to any power; and we can, by its aid, express any power of $a+b$ however high; thus, the hundredth power of $a+b$, will be $(a+b)^{100} = a^{100} + \frac{100}{1} \times a^{99}b + \frac{100 \times 99}{1 \times 2} + a^{98}b^2 + \frac{100 \times 99 \times 98}{1 \times 2 \times 3}$ $a^{97}b^3 + \frac{100 \times 99 \times 98 \times 97}{1 \times 2 \times 3 \times 4} a^{96}b^4 +$, &c.; from which the law of the preceding terms is evident.

ON THE TRANSPOSITION OF LETTERS, WHEREON THE LAST RULE RESTS.

707. In the coefficients we have just been considering it will be found that each term is presented as many times as the letters whereof the term consists can be transposed; or, in other words, the coefficient of each term is equal to the number of transpositions that its letters admit. Thus, in the second power the term *ba* is taken twice, that is to say, its coefficient is 2, for the order of its letters *ab* or *ba* can be changed only twice. The term *aa*, whose letters can undergo no change, is hence only found once. In the third power of $a+b$ the term *aab* can be written in three different ways, *aab*, *aba*, *baa*, and here the coefficient is 3. In the fourth power the coefficient of a^3b must be 4, because *aaab* admits of four different arrangements, *aaab*, *aaba*, *abaa*, *baaa*, and so on. It thence becomes desirable to know in how many different ways a given number of different letters may be arranged. Now, beginning with the simplest case, namely, *a* and *b*, we see at a glance that only two transpositions, namely *ab* and *ba*, can take place. If we have three letters, we see that each of the three may take the first place, while the two others admit of two transpositions. Thus, making *a* the first letter, we have *abc*, *acb*; if *b* is the first, we have *bac*, *bca*; but if *c* is made the first, we have *cab*, *cba*. Hence the whole number of arrangements is $3 \times 2 = 6$. If four letters, *abcd*, occur, each may be placed first, and we know the three others are capable of six different arrangements; hence the whole number of transpositions is $4 \times 6 = 24$, or $4 \times 3 \times 2 \times 1$. If the number of letters be five, we have $5 \times 24 = 120$, or $5 \times 4 \times 3 \times 2 \times 1$. Whatever, then, the number of letters, provided they be different, the number of transpositions is easily determined, and, up to the number ten, are subjoined in the following table:—

Number of letters.	Number of transpositions.
I	$1 = 1$
II	$2 \times 1 = 2$
III	$3 \times 2 \times 1 = 6$
IV	$4 \times 3 \times 2 \times 1 = 24$
V	$5 \times 4 \times 3 \times 2 \times 1 = 120$
VI	$6 \times 5 \times 4 \times 3 \times 2 \times 1 = 720$
VII	$7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = 5040$
VIII	$8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = 40320$
IX	$9 \times 8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = 362880$
X	$10 \times 9 \times 8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = 3628800$

The numbers, however, in this table can only be used when the letters are all different; and if two or more of them are alike, the number of transpositions becomes much less; as, if the letters were all alike, there could be but one arrangement. Our next object, then, will be to find how the numbers in the table diminish from similarity of letters. We have seen that when two similar letters occur, only one arrangement can be made, consequently the number above found is reduced one half, or must be divided by 2. If these letters are alike, the six transpositions are reduced to one, whence the number in the table must be divided by $6 = 3 \times 2 \times 1$. And, in the same way, when four letters are alike, we must divide the number in the table by $24 = 4 \times 3 \times 2 \times 1$, &c.

708. Thus there is no difficulty in ascertaining the number of transpositions the letters *aaabbc* may undergo; for, if they were all different, they would admit of $6 \times 5 \times 4 \times 3 \times 2 \times 1$ transpositions. But as *a* occurs three times, we must divide the number of transpositions by $3 \times 2 \times 1$; and as *b* occurs twice, we must again divide by 2×1; the numbers required, therefore, will be $\frac{6 \times 5 \times 4 \times 3 \times 2 \times 1}{3 \times 2 \times 1 \times 2 \times 1} = 5 \times 4 \times 3 = 60$.

709. We shall now apply the rule in the example of the seventh power of $a+b$, or $(a+b)^7$. The first term is a^7, which only occurs once; and, as all the other terms have seven letters, the number of transpositions for each term would be $7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1$ if the letters were all different. But the second term a^6b contains six letters alike, hence

the product last mentioned must be divided by 6 × 5 × 4 × 3 × 2 × 1, whence the coefficient will be $\frac{7\times6\times5\times4\times3\times2\times1}{6\times5\times4\times3\times2\times1}=\frac{5040}{720}=\frac{7}{1}$ or 7.

710. In the third term a^5bb, the same letter a occurs five times and the same letter b twice, the total number of letters being seven all through the power. We have here, then, to divide the number which seven transpositions give by 5 × 4 × 3 × 2 × 1, and then by 2 × 1, whence we have the coefficient $=\frac{7\times6\times5\times4\times3\times2\times1}{5\times4\times3\times2\times1\times2\times1}=\frac{5040}{240}=\frac{21}{1}$ or 21. It will be unnecessary to proceed with the remaining terms, the mode of finding the coefficient must be obvious. From what has been already said we shall find that the above rule enables us to find all the powers of roots consisting of more than two terms. Let us, for instance, apply them to the third power of $a+b+c$, the terms whereof must be formed by all the possible combinations of the three letters, each term having for its coefficient the number of its transpositions as above. The third power of $a+b+c$ will be found by multiplication to be $a^3+3aab+3aac+3abb+6abc+3acc+b^3+3bb+3bcc+c^3$.

711. Now, suppose $a=1$, $b=1$, $c=1$, the cube of 1 + 1 + 1 or of 3 will be 1 + 3 + 3 + 3 + 6 + 3 + 1 + 3 + 3 + 1 = 27, and the rule is thereby confirmed.

THE EXPRESSION OF IRRATIONAL POWERS BY INFINITE SERIES.

712. If we had supposed $a=1$, $b=1$, and $c=-1$, we should have found for the cube of 1 + 1 − 1, that is, of 1, 1 + 3 − 3 + 3 − 6 + 3 + 1 − 3 + 3 − 1 = 1.

713. In subsection 705. we have shown the method of finding any power of $a+b$. Suppose the exponent undetermined, but expressed by n, we shall have the rule there laid down —

$$(a+b)^n=a^n+\frac{n}{1}a^{n-1}b+\frac{n}{1}\times\frac{n-1}{2}a^{n-2}b^2+\frac{n}{1}\times\frac{n-1}{2}\times\frac{n-2}{3}a^{n-3}b^3+\frac{n}{1}\times\frac{n-1}{2}\times\frac{n-2}{3}$$
$$\times\frac{n-3}{4}a^{n-4}b4+,\ \&c.$$

If the same power of the root $a-b$ were required, we should have only to change the signs of the even terms, and should have

$$(a-b)^n=a^n-\frac{n}{1}a^{n-1}b+\frac{n}{1}+\frac{n-1}{2}a^{n-2}b^2-\frac{n}{1}\times\frac{n-1}{2}\times\frac{n-2}{3}a^{n-3}b^3+\frac{n}{1}\times\frac{n-1}{2}\times\frac{n-2}{3}$$
$$\times\frac{n-3}{4}a^{n-4}b^4,\ \&c.$$

714. These formulæ are useful from the facility they afford in expressing all kinds of radicals. It has already been seen that all irrational quantities may assume the form of powers whose exponents are fractional, and that $\sqrt[2]{a}=a^{\frac{1}{2}}$; $\sqrt[3]{}=a^{\frac{1}{3}}$; and $\sqrt[4]{a}=a^{\frac{1}{4}}$. We have, also, then $\sqrt[2]{(a+b)}=(a+b)^{\frac{1}{2}}$; $\sqrt[3]{(a+b)}=(a+b)^{\frac{1}{3}}$; and $\sqrt[4]{(a+b)}=(a+b)^{\frac{1}{4}}$, &c. Whence, if the square root of $a+b$ is required, we have only in the general formula to substitute the fraction $\frac{1}{2}$ for the exponent n, and we shall have, first, for the coefficients — $\frac{n}{1}=\frac{1}{2}$; $\frac{n-1}{2}=-\frac{1}{4}$; $\frac{n-2}{3}=-\frac{1}{2}$; $\frac{n-3}{4}=-\frac{5}{8}$; $\frac{n-4}{5}=-\frac{7}{10}$; $\frac{n-5}{6}=-\frac{9}{12}$. Then, $a^n=a^{\frac{1}{2}}=\sqrt{a}$, and $a^{n-1}=\frac{1}{\sqrt{a}}$; $a^{n-2}=\frac{1}{a\sqrt{a}}$; $a^{n-3}=\frac{1}{aa\sqrt{a}}$, &c. : or the powers of a may be expressed as follows: $a^{n-1}=\frac{\sqrt{a}}{a}$; $a^{n-}=\frac{a^n}{a^2}=\frac{\sqrt{a}}{a}$; $a^{n-3}=\frac{a^n}{a^3}=\frac{\sqrt{a}}{a^3}$; $a^{n-4}=\frac{a^n}{a^3}=\frac{\sqrt{a}}{a^4}$, &c.
The square root, then, of $a+b$ may be expressed in the following manner,

$$\sqrt{(a+b)}=\sqrt{a}+\tfrac{1}{2}b\frac{\sqrt{a}}{a}-\tfrac{1}{2}\times\tfrac{1}{4}bb\frac{\sqrt{a}}{aa}+\tfrac{1}{2}\times\tfrac{1}{4}\times\tfrac{3}{8}b^3\frac{\sqrt{a}}{a^3}-\tfrac{1}{2}\times\tfrac{1}{4}\times\tfrac{3}{8}\times\tfrac{5}{8}b^4\frac{\sqrt{a}}{a^4},\ \&c.$$

715. Hence, if a be a square number, the value of $\sqrt{a}$ may be assigned, and the square root of $a+b$ may also be expressed by an infinite series without any radical sign. Suppose, for instance, $a=cc$, we shall have $\sqrt{a}=c$; then $\sqrt{(cc+b)}=c+\frac{1}{2}\times\frac{b}{c}-\frac{1}{8}\frac{bb}{c^3}+\frac{1}{16}\times\frac{b^3}{c}-\frac{5}{128}\times\frac{b^4}{c^7}$, &c. So that there is no number whose square root may not be extracted in the same way; for every number may be resolved into two parts, one whereof is a square, represented by cc. Thus, if we require the square root of 6, make $6=4+2$, then $cc=4$, $c=2$, $b=2$, whence results $\sqrt{6}=2+\frac{1}{2}-\frac{1}{16}+\frac{1}{64}-\frac{5}{1024}$, &c.; and, taking only the two leading terms of this series, we find $2^{\frac{1}{2}}=\frac{5}{2}$, whose square $\frac{25}{4}$ is $\frac{1}{4}$ greater than 6; but if we take three terms, we shall have $2\frac{7}{16}=\frac{39}{16}$, whose square $\frac{1521}{256}$ is still $\frac{15}{256}$ too small. As $\frac{5}{2}$ in this example approaches very nearly to the true value of $\sqrt{6}$, we will take for 6 its equivalent quantity $\frac{25}{4}-\frac{1}{4}$. Thus $cc=\frac{25}{4}$; $c=\frac{5}{2}$; $b=\frac{1}{4}$; and using the two leading terms, we find $\sqrt{6}=\frac{5}{2}+\frac{1}{2}\times\frac{-\frac{1}{4}}{\frac{5}{2}}=\frac{5}{2}-\frac{1}{2}\times\frac{\frac{1}{4}}{\frac{5}{2}}=\frac{5}{2}-\frac{1}{20}=\frac{49}{20}$, and the square of this fraction being $\frac{2401}{400}$, exceeds the $\sqrt{6}$ only by $\frac{1}{400}$.

716. Now, taking $6=\frac{2401}{400}-\frac{1}{400}$, so that $c=\frac{49}{20}$ and $b=\frac{1}{400}$, and still confining ourselves to the two leading terms, we have $\sqrt{6}=\frac{49}{20}+\frac{1}{2}\times-\frac{\frac{1}{400}}{\frac{49}{20}}=\frac{49}{20}-\frac{1}{2}\times\frac{\frac{1}{400}}{\frac{49}{20}}=\frac{49}{20}-\frac{1}{1960}=\frac{4801}{1960}$, the square whereof is $\frac{23049601}{3841600}$. Now 6, when reduced to the same denominator, is $=\frac{23049600}{3841600}$; the error, therefore, is only $\frac{1}{3841600}$.

717. In a similar way may be expressed the cube root of $a+b$ by an infinite series. For, as

$\sqrt[3]{(a+b)}=(a+b)^{\frac{1}{3}}$, we shall have in the general formula $n=\frac{1}{3}$, and the coefficients will be $\frac{n}{1}=\frac{1}{3}$; $\frac{n-1}{2}=-\frac{1}{3}$; $\frac{n-2}{3}=-\frac{5}{9}$; $\frac{n-3}{4}=-\frac{2}{3}$; $\frac{n-4}{5}=-\frac{11}{15}$, &c., and for the powers of a we have $a^n=\sqrt[3]{a}$; $a^{n-1}=\frac{\sqrt[3]{a}}{a}$; $a^{n-2}=\frac{\sqrt[3]{a}}{aa}$; $a^{n-3}=\frac{\sqrt[3]{a}}{a^3}$, &c. Then $\sqrt[3]{(a+b)}=\sqrt[3]{a}+\frac{1}{3}\times b\frac{\sqrt[3]{a}}{a}+\frac{1}{9}\times bb\frac{\sqrt[3]{a}}{aa}+\frac{5}{81}\times b^3\frac{\sqrt[3]{a}}{a^3}-\frac{10}{243}\times b^4\frac{\sqrt[3]{a}}{a^4}$, &c. But if a be a cube or $a=c^3$, we have $\sqrt[3]{a}=c$ and the radical signs will vanish, for we shall have $\sqrt[3]{(c^3+b)}=c+\frac{1}{3}\times\frac{b}{cc}-\frac{1}{9}\times\frac{bb}{c^5}+\frac{5}{81}\times\frac{b^3}{c^8}-\frac{10}{243}\times\frac{b^4}{c^{11}}+$ &c.

718. Thus we arrive at a formula, enabling us by approximation, as it is called, to find the cube root of any number, because every number may be resolved into two parts, as c^3+b, whereof the first is a cube. If, for example, we are required to determine the cube root of 2, we represent 2 by $1+1$, so that $c=1$ and $b=1$, consequently $\sqrt{2}=1+\frac{1}{3}-\frac{1}{9}+\frac{5}{81}$, &c. The two leading terms of which series make $1\frac{1}{3}=\frac{4}{3}$, the cube of which, $\frac{64}{27}$, is too great by $\frac{10}{27}$. Let us then make $2=\frac{64}{27}-\frac{10}{27}$; we shall now have $c=\frac{4}{3}$, and $b=-\frac{10}{27}$, and therefore $\sqrt[3]{2}=\frac{4}{3}+\frac{1}{3}\times\frac{-\frac{10}{27}}{\frac{16}{9}}$. These two terms give $\frac{4}{3}-\frac{5}{72}=\frac{91}{72}$, the cube whereof is $\frac{753571}{373248}$. But $2=\frac{746496}{373248}$; so that the error is $\frac{7075}{373248}$. Thus we may approximate the root; and the faster, as a greater number of terms is taken.

RESOLUTION OF NEGATIVE POWERS.

719. It has already been seen that $\frac{1}{a}$ may be expressed by a^{-1}. For the same reason, $\frac{1}{a+b}$ may be represented by $(a+b)^{-1}$; hence the fraction $\frac{1}{a+b}$ may be considered as a power of $a+b$, namely, that whose exponent is -1; hence we conclude that the series already found as the value of $(a+b)^n$ will extend to this case.

720. As $\frac{1}{a+b}$ is the same as $(a+b)^{-1}$, let us assume, in the general formula, $n=-1$; then for coefficients we shall first have $\frac{n}{1}=-1$; $\frac{n-1}{2}=-1$; $\frac{n-2}{3}=-1$; $\frac{n-3}{4}=-1$, &c. For the powers of a we shall then have $a^n=a^{-1}=\frac{1}{a}$; $a^{n-1}=a^{-2}=\frac{1}{a^2}$; $a^{n-2}=\frac{1}{a^3}$; $a^{n-3}=\frac{1}{a^4}$, &c. So that $(a+b)^{-1}=\frac{1}{a+b}=\frac{1}{a}-\frac{b}{a^2}+\frac{b}{a^3}-\frac{b^3}{a^4}+\frac{b^4}{a^5}-\frac{b^5}{a^6}$, &c., which is the same series before found by division.

721. Now, $\frac{1}{(a+b)^2}$ being the same as $(a+b)^{-2}$, let us reduce it to an infinite series; for which purpose we must suppose $n=-2$, and we have for the coefficients $\frac{n}{1}=-\frac{2}{1}$; $\frac{n-1}{2}=-\frac{3}{2}$; $\frac{n-2}{3}=-\frac{4}{3}$; $\frac{n-3}{4}=-\frac{5}{4}$, &c. And for the powers of a; $a^n=\frac{1}{a^2}$; $a^{n-1}=\frac{1}{a^3}=$; $a^{n-2}=\frac{1}{a^4}$; $a^{n-3}=\frac{1}{a^5}$, &c. We therefore obtain $(a+b)^{-2}=\frac{1}{(a+b)^2}=\frac{1}{a^2}-\frac{2}{1}\times\frac{b}{a^3}+\frac{2}{1}\times\frac{3}{2}\times\frac{bb}{a^4}-\frac{2}{1}\times\frac{3}{2}\times\frac{4}{3}\times\frac{b^3}{a^5}+\frac{2}{1}\times\frac{3}{2}\times\frac{4}{3}\times\frac{5}{4}\frac{b^4}{a^6}$, &c. Now $\frac{2}{1}=2$; $\frac{2}{1}\times\frac{3}{2}=3$; $\frac{2}{1}\times\frac{3}{2}\times\frac{4}{3}=4$; $\frac{2}{1}\times\frac{3}{2}\times\frac{4}{3}\times\frac{5}{4}=5$, &c. We have, therefore, $\frac{1}{(a+b)^2}=\frac{1}{a^2}-2\frac{b}{a^3}+3\frac{b^2}{a^4}-4\frac{b^3}{a^5}+5\frac{b^4}{a^6}-6\frac{b^5}{a^7}+7\frac{b^6}{a^8}$, &c. To proceed, let us take $n=-3$, and we have a series expressing the value of $\frac{1}{(a+b)^3}$, or of $(a+b)^{-3}$. The coefficients will be $\frac{n}{1}=-\frac{3}{1}$; $\frac{n-1}{2}=-\frac{4}{2}$; $\frac{n-2}{3}=-\frac{5}{3}$; $\frac{n-3}{4}=-\frac{6}{4}$, &c., and the powers of a become $a^n=\frac{1}{a^3}$; $a^{n-1}=\frac{1}{4}$; $a^{n-2}=\frac{1}{a^5}$, &c., which gives $\frac{1}{(a+b)^3}=\frac{1}{a^3}-\frac{3}{1}\frac{b}{a^4}+\frac{3}{1}\times\frac{4}{2}\frac{b^2}{a^5}-\frac{3}{1}\times\frac{4}{2}\times\frac{5}{3}\frac{b^3}{a^6}+\frac{3}{1}\times\frac{4}{2}\times\frac{5}{3}\times\frac{6}{4}\frac{b^4}{a^7}$, and $c=\frac{1}{a^3}-3\frac{b}{a^4}+6\frac{b^2}{a^5}-10\frac{b^3}{a^6}+15\frac{b^4}{a^7}-21\frac{b^5}{a^8}+28\frac{b^6}{a^9}-36\frac{b^7}{a^{10}}+45\frac{b^3}{a^{11}}$, &c.

722. If we make $n=-4$, we have for the coefficients $\frac{n}{1}=-\frac{4}{1}$; $\frac{n-1}{2}=-\frac{5}{2}$; $\frac{n-2}{3}=-\frac{6}{3}$; $\frac{n-3}{4}=\frac{7}{4}$, &c.; and for the powers $a^n=\frac{1}{a^4}$; $a^{n-1}=\frac{1}{a^5}$; $a^{n-2}=\frac{1}{a^6}$; $a^{n-3}=\frac{1}{a^7}$; $a^{n-4}=\frac{1}{a^8}$, &c.; whence we obtain $\frac{1}{(a+b)^4}=\frac{1}{a^4}-\frac{4}{1}\times\frac{b}{a^5}+\frac{4}{1}\times\frac{5}{2}\times\frac{b^2}{a^6}-\frac{4}{1}\times\frac{5}{2}\times\frac{6}{3}\frac{b^3}{a^7}+\frac{4}{1}\times\frac{5}{2}\times\frac{6}{3}\times\frac{7}{4}\times\frac{b^4}{a^8}$; and $c=\frac{1}{a^4}-4\frac{b}{a^5}+10\frac{b^2}{a^6}-20\frac{b^3}{a^7}+35\frac{b^4}{a^8}-56\frac{b^5}{a^9}+$, &c.

723. From the cases considered, we are able to conclude that for any negative power of $a+b$, we shall have

$$\frac{1}{(a+b)^m}=\frac{1}{a^m}-\frac{m}{1}\times\frac{b}{a^{m+1}}+\frac{m}{1}\times\frac{m+1}{2}\times\frac{b^2}{a^{m+2}}-\frac{m}{1}\times\frac{m+1}{2}\times\frac{m+2}{3}\times\frac{b^3}{a^{m+3}}, \text{ \&c.}$$

by means of which formula all such fractions may be transformed into infinite series, substituting also fractions or fractional exponents for m, in order to express irrational quantities.

724. In further illustration of this subject, we recal to mind that $\frac{1}{a+b}-\frac{1}{a}-\frac{b}{a^2}+\frac{b^2}{a^3}-\frac{b^3}{a^4}+\frac{b^4}{a^5}-\frac{b^5}{a^6}+$, &c.; now this series, therefore, multiplied by $a+b$, ought to produce 1; which is found to be the truth by performing the multiplication thus —

$$\begin{array}{l}
\frac{1}{a}-\frac{b}{a^2}+\frac{b^2}{a^3}-\frac{b^3}{a^4}+\frac{b^4}{a^5}-\frac{b^5}{a^6}+\text{\&c.} \\
a+b \\
\hline
1-\frac{b}{a}+\frac{b^2}{a^2}-\frac{b^3}{a^3}+\frac{b^4}{a^4}-\frac{b^5}{a^5}+\text{\&c.} \\
\quad +\frac{b}{a}-\frac{b^2}{a^2}+\frac{b^3}{a^3}-\frac{b^4}{a^4}+\frac{b^5}{a^5}-\text{\&c.} \\
\hline
1
\end{array}$$

725. It has also been shown that $\frac{1}{(a+b)^2}=\frac{1}{aa}-\frac{2b}{a^3}+\frac{3bb}{a^4}-\frac{4b^3}{a^5}+\frac{5b^4}{a^6}-\frac{6b^5}{a^7}$, &c. If, as before, this series be multiplied by $(a+b)^2$ or $aa+2ab+bb$, the product will be found to be $=1$.

726. If the series found for the value of $\frac{1}{(a+b)^2}$ be multiplied by $a+b$ only, the product ought to be the fraction $\frac{1}{a+b}$, or be equal to the series already found, namely, $\frac{1}{a}-\frac{b}{a^2}+\frac{bb}{a^3}-\frac{b^3}{a^4}+\frac{b^4}{a^5}$, &c.; and that, on multiplication, will be found to be the case.

ARITHMETICAL RATIO.

727. The relation which one quantity bears to another, with respect to magnitude, is called a *ratio*. It is evident that no relation can exist between quantities that are not of a similar kind; as, for example, a number must be compared with a number, a line with a line, &c. The magnitudes of quantities may be compared in two ways. In the first, they may be compared with regard to their *difference*; and then the question asked is, how much one quantity is greater or less than another? The relation in this respect, which quantities bear to each other, is called their *arithmetical ratio*. The other way in which they may be compared is, by inquiring how often one quantity is greater than another? and this relation between quantities is called their *geometrical ratio*. The term ratio, when simply applied, is generally understood in the latter sense; and we shall reserve the word *ratio* and *relation* to express geometrical ratios.

728. By subtraction, the difference is found between two numbers; hence the question, how much the one is greater than the other, is easily resolved. Thus, between two equal numbers, the difference being nothing, if we are asked how much one of the numbers is greater than the other, the answer is, by nothing. Thus, 8 being $=2\times 4$, the difference between 8 and 2×4 is 0.

729. When two numbers, as 5 and 3, are not equal, and we require to know how much 5 is greater than 3, the answer is 2, and it is obtained by subtracting 3 from 5. So 17 is greater than 7 by 10, and 25 exceeds 8 by 17. There are therefore three things relative to the subject for our consideration: 1st, the greater of the two numbers; 2d, the less; and 3d, the difference; which three quantities are so connected, that two of the three being given, the third may also be determined. Suppose the greater number $=a$, the less $=b$, and the difference $=d$, the difference will be found by subtracting b from a, so that $d=a-b$, whence we find d, if a and b are given.

730. But if the difference and the less b of the two numbers are given, the greater number is determined by adding the difference to the less number, which gives $a=b+d$; for if we take from $b+d$ the less number b, there remains d, which is the known difference. Let the number $=12$ and the difference $=8$, then the greater number $=20$. Lastly, if a the greater be given, and d the difference, b will be found by subtracting the difference from the greater number, that is, $b=a-d$.

731. The connection, then, among the numbers is of such a nature as to give these results:—1st. $d=a-b$; 2d. $a=b+d$; 3d. $b=a-d$; and, generally, if $z=x+y$, then $y=z-x$ and $x=z-y$. It must here be remarked, with respect to arithmetical ratios, that if any number, as c, be added to the numbers a and b, the difference is still the same. Thus, d being the difference between a and b, that number d will also be the difference between $a+c$ and $b+c$, and between $a-c$ and $b-c$. Thus, the difference between 20 and 8 being 12, such difference will remain the same whatever numbers we add to 20 and 12, and whatever numbers we subtract from them; for if $a-b=d$, we must have $(a+c)-(b+c)=d$, as also $(a-c)-(b-c)=d$. So, if the numbers be doubled, the difference will be double, and, generally, $na-nb=nd$, whatever be the value of a.

ARITHMETICAL PROPORTION.

732. When two arithmetical ratios or relations are equal, the equality is called an *arithmetical proportion*. Thus, if $a-b=p-q$, the difference between p and q being the same as that between a and b, these four numbers are said to form an arithmetical proportion, which is thus written, $a-b=p-q$. An arithmetical proportion, then, consists of four terms, which are such that, subtracting the second term from the first, the remainder is the same as when we subtract the fourth from the third; thus the numbers 24, 9, 23, 8, form an

arithmetical proportion, because $24-9=23-8$, which by some is written $24.9::23.8$. In any arithmetical proportion, as $a-b=p-q$, the second and third quantities may change places without changing the equality; for as $a-b=p-q$, add b to both sides, and we have $a=b+p-q$; and now subtracting p from both sides, we have $a-b=p-q$. In numbers, as $24-9=23-8$, so $24-23=9-8$. In an arithmetical proportion, the second term may take the place of the first, if the fourth be made to take the place of the third; thus, if $a-b=p-q$, we have $b-a=q-p$. For $b-a$ is the negative of $a-b$, and $q-p$ is the negative of $p-q$. But the great property of every arithmetical proportion is this, that the sum of the second and third terms is always equal to the sum of the first and fourth; a property which deserves particular consideration, and is expressed by saying that the sum of the *means* (middle terms) is equal to the sum of the *extremes* (extreme terms). Thus, since $24-9=23-8$, we have $9+23=24+8$, both being 32. The demonstration of this is as follows: Let $a-b=p-q$, add to both $b+q$, and we have $a+q=b+p$, that is, the sum of the first and fourth is equal to the sum of the second and third; and inversely, if four numbers, a, b, p, q, be such that the sum of the second and third is equal to that of the first and fourth, that is, if $b+p=a+q$, we may be sure that those numbers are in arithmetical proportion, and that $a-b=p-q$; for if $a+q=b+p$, subtracting from both sides $b+q$, we obtain $a-b=p-q$. Thus the numbers 24, 12, 27, 15, being such that the sum of the means $(12+27=39)$ is equal to the sum of the extremes $(24+15=39)$, we are certain that they form an arithmetical proportion, and consequently that $24-12=27-15$.

733. By this property, the following question is resolved: — The three first terms of an arithmetical proportion being given, to find the fourth, let a, b, p be the three first terms, and let the fourth, which is that sought, be represented by q. Then $a+q=b+p$; by subtracting a from both sides we have $q=b+p-a$. Hence it appears that the fourth term is found by adding together the second and third, and from their sum subtracting the first. Thus, suppose the three first terms are 24, 12, 27, the sum of the second and third is $=39$, from which subtract 24, the first, and we have 15 for the fourth term sought. When in an arithmetical proportion the second term is equal to the third, we have only three numbers, whose property is this, that the first minus the second is equal to the second minus the third, or that the differences between the first and second and between the second and third are equal. Of this kind are the numbers 23, 18, 13, since $23-18=18-3$. Three such numbers, as 23, 18, 13, are said to form a continued arithmetical proportion, called an *arithmetical progression*, particularly when a great number of such terms follow each other according to the same law. An arithmetical progression may be either *increasing* or *decreasing*; that is to say, the former when the terms go on increasing, as 5, 9, 13, and the latter when they go on diminishing, as 12, 9, 6.

734. Let us suppose the numbers a, b, c to be in arithmetical progression; then $a-b=b-c$; hence from the equality between the sum of the extremes and that of the means, $2b=a+c$, if we subtract a from both, we have $c=2b-a$: hence, when the two first terms a b of an arithmetical progression are given, the third is found by taking the first from twice the second. Thus let 2 and 5 be the two first terms of an arithmetical progression, the third will be $2\times5-2=8$; and the three numbers 2, 5, 8 give the proportion $2-5=5-8$. This method enables us to obtain, to any extent, an arithmetical progression; for we have only to find the fourth by means of the second and third in the same way as the third was determined by means of the first and second, and so on. Let a be the first term and b the second, the third will be $=2b-a$, the fourth $4b-2a-b=3b-2a$, the fifth will be $6b-4a-2b+a=4b-3a$, the sixth $=8b-6a-3b+2a=5b-4a$, &c.

ARITHMETICAL PROGRESSION.

735. Having in the preceding subsection seen the nature of arithmetical progression, we may perceive that the natural numbers written in their order (as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, &c.) form an increasing arithmetical progression, because they increase constantly by unity; and the series 23, 21, 19, 17, 15, 13, 11, 9, 7, 5, 3, 1 is also such a progression wherein the numbers constantly decrease by 2. The number or quantity by which an arithmetical progression increases or decreases is called the *difference*. Hence, if the first term and difference be given, we may continue it to any extent. For instance, let the first term $=3$, and the difference $=4$, we shall have the following increasing progression, 3, 7, 11, 15, 19, 23, 27, 31, 35, &c., wherein each succeeding term is found by adding the difference to the preceding one. It is usual to write the natural numbers 1, 2, 3, 4, &c. above the term of such an arithmetical progression, in order that we may perceive the rank held by any term in the progression. The numbers so written above the terms are called the indices, as in the following example: —

Indices - - -	1	2	3	4	5	6	7	8	9	10	11
Arithmetical progression	3,	7,	11,	15,	19,	23,	27,	31,	35,	39,	43, &c.;

in which we see 43 is the eleventh term.

736. Let a be the first term, and d the difference, the following will be the order of it: —

$$\begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ a, & a+d, & a+2d, & a+3d, & a+4d, & a+5d, & a+6d, \text{ \&c.} \end{array}$$

Whence it is evident, that any term of the progression may be found without the necessity of finding the intermediate ones merely by the first term, and the difference d; for example, the twelfth term, $=a+11d$, the thousandth term, $=a+999d$, and generally the last term $=a+(n-1)d$; hence it is only necessary to multiply the difference by the number of terms minus one, and to the product to add the first term. Thus, suppose an arithmetical progression of a hundred terms whose first term is $=6$, and the difference $=5$, then the last term will be $=99\times 5+6=501$.

737. Knowing the first term a, and the last z, the number of terms n, we can find the difference d. For since the last term $z=a+(n-1)d$, if we subtract a from both sides, we obtain $z-a=(n-1)d$. Then, by subtracting the first term from the last, we have the product of the difference multiplied by the number of terms minus 1. And dividing $z-a$ by $n-1$, the required value of the difference will be $=\frac{z-a}{n-1}$; from which results the following rule: subtract the first term from the last, divide the remainder by the number of terms minus 1, and the quotient will be the difference, by which the whole progression may be written —

Example. — Let the first term $=2$, the last 26, to find the difference,

$\frac{26-2}{9-1}=\frac{24}{8}$ the quotient $=3$ will be equal to the difference, and the progression will be as under: —

$$\begin{array}{ccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 2, & 5, & 8, & 11, & 14, & 17, & 20, & 23, & 26. \end{array}$$

738. Another example.—Let the first term $=2\frac{1}{3}$, the last $=12\frac{1}{2}$, the number of terms $=7$; then the difference will be

$$\frac{12\frac{1}{2}-2\frac{1}{3}}{7-1}=\frac{10\frac{1}{6}}{6}=\frac{61}{36}=1\frac{25}{36}, \text{ and the progression will be}$$

$$\begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 2\frac{1}{3}, & 4\frac{1}{36}, & 5\frac{13}{18}, & 7\frac{5}{12}, & 9\frac{1}{9}, & 10\frac{29}{36}, & 12\frac{1}{2}. \end{array}$$

739. If the first term a, the last term z, and the difference d be given, we may from these find the number of terms n. For, inasmuch as $z-a=(n-1)d$, if we divide the two sides by d, we have $\frac{z-a}{d}=n-1$, and n being greater by 1 than $n-1$, we have $n=\frac{z-a}{d+1}$; the number of terms is therefore found by dividing the difference between the first and last terms, or $z-a$ by the difference of the progression, and adding unity to the quotient $\frac{z-a}{d}$.

740. Thus, for example, let the first term $=4$, the last $=100$, and the difference $=12$; the number of terms will be $\frac{100-4}{12}+1=9$, and these nine terms will be

$$\begin{array}{ccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 4, & 16, & 28, & 40, & 52, & 64, & 76, & 88, & 100. \end{array}$$

Another example.—Let the first term $=3\frac{1}{3}$, the last $=7\frac{2}{3}$, and the difference $=1\frac{4}{9}$; the number of terms will be $\frac{7\frac{2}{3}-3\frac{1}{3}}{1\frac{4}{9}}+1=4$, which are $3\frac{1}{3}$, $4\frac{7}{9}$, $6\frac{2}{9}$, $7\frac{2}{3}$.

741. It must, however, be remarked, that the number of terms being necessarily an integer, if such a number had not been obtained for n in the foregoing examples, the questions would have been absurd; and if an integer number be not obtained for the value $\frac{z-a}{d}$, the question cannot be resolved; hence, in order that such questions may be possible, $z-a$ must be divisible by d.

742. It may now be concluded, then, that there are always four quantities for consideration in an arithmetical progression. 1. The first term, a. 2. The last term, z. 3. The difference, d. 4. The number of terms, n; and the relations of these to each other are such, that, if we know three of them, the fourth may be found. For, 1. If a, d, and n are known, we have $z=a+(n-1)d$. 2. If z, d, and n are known, we have $a=z-(n-1)d$. 3. If a, z, and n are known, we have $d=\frac{z-a}{n-1}$. 4. If a, z, and d are known, we have $n=\frac{z-a}{d}+1$.

SUMMATION OF ARITHMETICAL PROGRESSIONS.

743. To find the form of an arithmetical progression by adding all the terms together would be troublesome when the number of terms is very great; a rule has therefore been found by which the operation is much shortened. Let us first consider a particular given

progression, whose first term $=2$, difference $=3$, the last term $=29$, and the number of terms $=10$.

1	2	3	4	5	6	7	8	9	10
2,	5,	8,	11,	14,	17,	20,	23,	26,	29.

744. In this progression, the sum of the first and last term $=31$, the sum of the second and last but one $=31$, and so on; from which we conclude that the sum of any two terms equally distant, the one from the first, the other from the last term, is always equal to that of the first and last. It will not be difficult to discover the cause of this; for, suppose the first $=a$, the last $=z$, and the difference $=d$, the sum of the first and last is $=a+z$, and the second term being $=a+d$, and the last but one $=z-d$; the sum of these two terms is also $=a+z$. Again, the third term being $a+2d$, and the last term but two $=z=2d$, it is evident that the sum of these two terms also makes $a+z$. From this, the demonstration for the rest is obvious. Now, if we write the progression term by term twice over, but in one line, invert the order of the terms, and add the corresponding terms together, we shall have as follows: —

$$\begin{array}{l} 2+\ 5+\ 8+11+14+17+20+23+26+29 \\ 29+26+23+20+17+14+11+\ 8+\ 5+\ 2 \\ \hline 31+31+31+31+31+31+31+31+31+31 \end{array}$$

A series of equal terms, evidently equal to twice the sum of the given progression, whose number of terms being 10, the sum here exhibited will be $=10\times 31=310$. Hence, as this is twice the sum of the arithmetical progression, the sum required must be 155.

745. Treating in the same manner any arithmetical progression whose first term $=a$, last term $=z$, and number of terms $=n$, and writing as above shown, the progression direct and inverted, the one under the other, and adding term to term, we have a series or n terms each $=a+z$, whose sum will consequently be $=n(a+z)$, which will be twice the sum of the proposed arithmetical progression, and therefore $=\frac{n(a+z)}{2}$. From which flows a simple rule for finding the sum of an arithmetical progression. Multiply the sum of the first and last terms, and half the product will be the sum of the whole progression. We will illustrate this rule by an example. Let it be required to find the sum of the progression of the natural numbers, 1, 2, 3, &c. to 100. This, by the rule, will be $=\frac{100\times 101}{2}=50\times 101=5050$.

746. Let it be required to find the sum of an arithmetical progression whose first term is $=5$, the difference $=3$, and the number of terms $=32$: we must begin by using the rules in subsections 735. *et seq.*, by which we determine the last term to be $=5+\overline{31\times 3}=98$, after which the sum is immediately seen to be $=\frac{103\times 32}{2}=103\times 16=1648$. Generally, to find the sum of the whole progression, let the first term be $=a$, the difference $=d$, and the number of terms $=n$. Now, as by the preceding subsection the last term must be $=a+(n-1)d$, the sum of the first and last will be $2a+(n-1)d$; multiplying this sum by the number of terms n, we have $2na+n(n-1)d$; the sum required, therefore, will be $=na+\frac{n(n-1)d}{2}$, and this formula, applied to the preceding example, gives 1648, as before.

747. Suppose it required to add together all the natural numbers from 1 to n, we have for resolving the question the first term $=1$, the last term $=n$, and the number of terms $=n$, the sum required is $=\frac{nn+n}{2}=\frac{n(n+1)}{2}$. Let n be $=1766$, then the sum of all the numbers from 1 to $1766=883\times 1767=1560261$.

748. If a progression of uneven numbers be proposed, 1, 3, 5, 7, &c. continued to n terms, and the sum be required. We have the first term $=1$, the difference $=2$, the number of terms $=n$; the last term will therefore be $=1+(n-1)2=2n-1$, and, consequently, the sum $=nn$. Hence, whatever number of terms of this progression are added together, the sum will always be a square, namely, the square of the number of terms, as a view of the following table will render manifest: —

Indices - -	1	2	3	4	5	6	7	8	9	10, &c.
Progression -	1	3	5	7	9	11	13	15	17	19, &c.
Sum - - -	1,	4,	9,	16,	25,	36,	49,	64,	81,	100, &c.

The subjoined table exhibits formulæ for differences up to 10: —

If $d=1$ the sum will be $=n+\frac{n(n-1)}{2}=\frac{nn+n}{2}$

$d=2$ — $=n+\frac{2n(n-1)}{2}=nn$

$d=3$ — $=n+\frac{3n(n-1)}{2}=\frac{3nn-n}{2}$

$d=4$ — $=n+\frac{4n(n-1)}{2}=2nn-n$

If $d=5$ the sum will be $=n+\frac{5n(n-1)}{2}=\frac{5nn-3n}{2}$

$d=6$ — $=n+\frac{6n(n-1)}{2}=3nn-2n$

$d=7$ — $=n+\frac{7n(n-1)}{2}=\frac{7nn-5n}{2}$

$d=8$ — $=n+\frac{8n(n-1)}{2}=4nn-3n$

$d=9$ — $=n+\frac{9n(n-1)}{2}=\frac{9nn-7n}{2}$

$d=10$ — $=n+\frac{10n(n-1)}{2}=n.$

GEOMETRICAL RATIO.

749. We have before observed that the *geometrical ratio* of two numbers is found by answering the question *how many times* is one of those numbers greater than the other, the quotient being the ratio required. Three things here present themselves for consideration. Firstly, the first of the two given numbers, which is called the *antecedent*; secondly, the other number, which is called the *consequent*; thirdly, the *ratio* of the two numbers, or quotient arising from the division of the antecedent by the consequent. Thus, if the relation of the numbers 18 and 12 be sought, 18 being the antecedent, and 12 the consequent, the ratio will be $\frac{18}{12}=1\frac{6}{12}$, whence we see the antecedent contains the consequent once and a half. Geometrical relations are generally represented by a point placed above another between the antecedent and the consequent. Thus $a : b$ signifies the geometrical relation of these two numbers, or the ratio of b to a. The sign just mentioned has, in a previous page, been given as indicating division, and it is on that account here used, because, in order to know the ratio, we divide a by b. The relation is merely read a is to b. On this account relation is expressed by a fraction whose numerator is the antecedent and denominator the consequent. It is hardly necessary to say that this fraction should, for perspicuity sake, appear in its lowest terms. Thus $\frac{18}{12}$, if both terms be divided by 6, becomes $\frac{3}{2}$.

750. Hence relations differ as their ratios are different; and there are, of course, as many kinds of geometrical relations as we can imagine different ratios. The first kind is that wherein the ratio becomes unity, which, of course, happens when the two numbers are equal, as in 3 : 3, 4 : 4; $a : a$, and because the ratio here is 1, it is called the relation of equality. The relation then follows in which the ratio is another whole number; in 4 : 2 the ratio is 2, and is called a *double* ratio; in 12 : 4, the ratio being 3, it is called a *triple* ratio; in 24 : 6 the ratio is 4, and is called a *quadruple* ratio. It is necessary, also, to notice those relations whose ratios are expressed by fractions, as 12 : 9, where the ratio is $\frac{4}{3}$, or $1\frac{1}{3}$; 18 : 27, where the ratio is $\frac{2}{3}$, &c. Those relations, as 6 : 12, 5 : 15, &c., wherein the consequent contains exactly twice, thrice, &c. the antecedent, are sometimes called *subduple*, *subtriple*, &c. ratios. The term *rational* is applied to ratios that are expressible numbers, the antecedent and consequent being integers, as 11 : 7, 8 : 15, &c.; and that of *irrational*, or *surd*, is applied to ratios neither expressible by integers nor by fractions, as $\sqrt{5} : 8$, $4 : \sqrt{3}$.

751. If a be the antecedent, b the consequent, and d the ratio, $d=\frac{a}{b}$. Were the consequent b given with the ratio, we should find $a=bd$, for bd divided by b gives d. Finally, when the antecedent a is given, and the ratio d the consequent, $b=\frac{a}{d}$; for, dividing the antecedent a by the consequent (or its equivalent) $\frac{a}{d}$, we obtain the quotient d, that is, the ratio. In whatever way we multiply or divide the consequent and antecedent by the same number, every relation $a : b$ remains the same, because the ratio is the same. Let d be the ratio of $a : b$, we have then $d=\frac{a}{b}$: now the relation $na : nb$ is still $\frac{a}{b}=d$, and likewise $\frac{a}{n} : \frac{b}{n}$ is still $\frac{a}{b}=d$. So, also, when a ratio has been reduced to its lowest terms, the relation is easily perceived and enunciated; for, let the ratio $\frac{a}{b}$ be reduced to its lowest terms $\frac{p}{q}$, we say, $a : b=p : q$, $a : b :: p : q$, which is read a is to b as p is to q. Thus the ratio of the relation 6 : 3 being $\frac{6}{3}$, or 2, we say, 6 : 3 = 2 : 1. So, 18 : 12 = 3 : 2, and 2418 : = 4 : 3, &c. But if the ratio be not susceptible of abridgment, the relation does not become more evident, and we do not simplify a relation by saying 9 : 7 = 9 : 7. We may, however, change the relation of two large numbers into one more simple and evident by reducing both to their lowest terms, for we may say, 14484 : 7242 = 2 : 1, or 15819 : 10546 = 3 : 2, or 57600 : 25200 = 16 : 7. All relations, therefore, should be reduced to the lowest possible numbers, which is readily done by dividing the two terms of the relation by their greatest common divisor. Thus, to reduce the relation 57600 : 25200 to that of 16 : 7, we have only to perform the single operation of dividing the numbers 576 and 252 by their greatest common divisor, 36. The method of finding a common divisor of two given numbers will be given in the following subsection.

GREATEST COMMON DIVISOR.

752. There are many numbers whose only common divisor is unity, and where the numerator and denominator belong to this class, the fraction cannot be reduced to a more convenient form. Such is the case with the numbers 48 and 35; hence, as the division of 48 : 35 can only be divided by 1, their relation cannot be more simply expressed. But if two numbers have a common divisor, the greatest they have is found by the following rule. Divide the greater by the lesser number, and divide the preceding divisor by the remainder; the remainder resulting from the last division again becomes the divisor for a third division wherein the preceding divisor is to be the dividend. This operation being repeated till we arrive at a division to which no remainder is left, the last divisor will be found to be the greatest common measure or divisor of the two given numbers. Now, let us apply this to the two numbers 504 and 312, whereof we require the greatest common divisor.

312)504(1
312
192)312(1
192
120)192(1
120
72)120(1
72
48)72(1
48
24)48(2
48
0

Here we perceive that the last divisor is 24, and dividing 504 and 312 by it, we find that the relation 504 : 312 is reduced to the form 21 : 13.

Let the relation 456 : 721 be given to find the greatest common divisor.

456)721(1
456
265)456(1
265
191)265(1
191
74)191(2
148
43)74(1
43
31)43(1
31
12)31(2
24
7)12(1
7
5)7(1
5
2)5(2
4
1)2(2
2
0

In this case 1 is the greatest common divisor, and we cannot express the relation 721 : 456 by less numbers, nor reduce it to less terms, than those in which it appears.

753. To demonstrate this rule, let a be the greater and b the less of the given numbers, and let d be one of their common divisors; it is evident that a and b being divisible by d, we may also divide the quantities $a-b$, $a-2b$, $a-3b$, and, in general, $a-nb$, by d. Equally true must be the converse, that is to say, if the numbers b and $a-nb$ are divisible by d, the number a will be also divisible by d. Farther, if d be the greatest common divisor of two numbers b and $a-nb$, it will also be the greatest common divisor of the two numbers a and b: for if a greater common divisor than d could be found for the numbers a and b, it would also be a common divisor of b and $a-nb$, and consequently d would not be the greatest common divisor of these two numbers. But we have supposed d the greatest divisor common to b and $a-nb$, wherefore it must also be the greatest common divisor of a and b. With these considerations before us, let us, according to the rule, divide the greater number a by the lesser b, and let us suppose the quotient $=n$; the remainder will be $a-nb$, which must be less than b. This remainder $a-nb$ having the same greatest common divisor with b as the numbers a and b, it is only necessary to repeat the division, dividing the preceding divisor b by the remainder $a-nb$; and the new remainder which is obtained will still have with the preceding divisor the same greatest common divisor, and so on. Proceeding in this way till we arrive at a division without a remainder, that is, in which the remainder is nothing, let p be the last divisor contained exactly a certain number of times in its dividend, which will therefore be divisible by p, and will have the form mp; so that the numbers p and mp are both divisible by p, and as no number can be divided by a number greater than itself, it is clear that they have no greater common divisor. Therefore the last divisor is the greatest common divisor of the given numbers a and b, and the rule laid down is thus demonstrated.

GEOMETRICAL PROPORTION

754. When their ratios are equal, geometrical relations are equal, such equality of relations being called a *geometrical proportion:* thus we write $a:b=c:d$, or $a:b::c:d$, thereby indicating that the relation $a:b$ is equal to the relation $c:d$, which is expressed in language a is to b as c to d. Such a proportion is $4:1=12:3$, for the relation of $4:1$ is $\frac{4}{1}$, and this also is the relation of $12:3$. Thus, $a:b=c:d$ being a geometrical proportion, the ratio is the same on both sides, and $\frac{a}{b}=\frac{c}{d}$; and, reciprocally, if the fractions $\frac{a}{b}$ and $\frac{c}{d}$ are equal, we have $a:b::c:d$. Hence, a geometrical proportion consists of four terms, such that the first divided by the second gives the same quotient as the third divided by the fourth; and hence, also, is deduced an important property common to all geometrical proportion, namely, that the product of the first and last term is always equal to the product of the second and third, or, in more simple language, the product of the extremes is equal to the product of the means.

755. To demonstrate this last named property, let us take the geometrical proportion $a:b=c:d$, so that $\frac{a}{b}=\frac{c}{d}$. Multiplying both these fractions by b, we obtain $a=\frac{bc}{d}$; and again multiplying both sides by d, we have $ad=bc$. Now, ad is the product of the extremes, bc that of the means, and these two products are found to be equal. Reciprocally, when a, b, c, d are such numbers that the product of the extremes a and d are equal to the product of the means b and c, we may be certain that they form a geometrical proportion. For, since $ad=bc$, we have only to divide both sides by bd, which gives us $\frac{ad}{bd}=\frac{bc}{bd}$, or $\frac{a}{b}=\frac{c}{d}$, and therefore $a:b=c:d$.

756. The transposition of the four terms of a geometrical proportion, as $a:c=b:d$, does not destroy the proportion, for the rule being that the product of the extremes is equal to the product of the means, or $ad=bc$, we may also say, 1st, $b:a=d:c$; 2d, $a:c=b:d$; 3d, $d:b=c:a$; 4th, $d:c=b:a$. Besides these, some others may be deduced from the same proportions $a:b=c:d$; thus we may say $a+b:a=c+d:c$; that is, the first term added to the second is to the first as the third added to the fourth is to the third. So, also, $a-b:a=c-d:c$. For, taking the product of the extremes, we have $ac-bc=ac-ad$, which leads to the equality $ad=bc$.

757. All the proportions deduced from $a:b=c:d$ may be generally represented as follows: —

$$ma+nb:pa+qb=mc+nd:pc+qd;$$

For the product of the extremes is $mpac+npbc+mqad+nqbd$, which, because $ad=bc$, becomes $mpac+npbc+mqbc+nqbd$. Farther, the product of the means is $mpac+mqbc+npad+nqbd$; or, as $ad=bc$, it is $mpac+mqbc+npbc+nqbd$; so that the two products are equal. It is therefore evident that from any geometrical proportion an infinite number of others may be deduced: take, for example, $9:3=18:6$, and we may have

$$3 : 9=6 : 18; \quad 9 : 18=3 : 6; \quad 12 : 9=24 : 18;$$
$$3 : 3=6 : 6; \quad 12 : 24=3 : 6; \quad 12 : 3=24 : 6;$$

besides many others.

758. Since in every geometrical proportion the products of the extremes and of the means are equal, we may, when the three first terms are known, find the fourth from them. Thus, suppose the three first terms to be $9 : 3=18$: the quantity sought. Now the product of the means is 3×18, or 54; the fourth term must therefore be 1, which multiplied into the first will produce that number; if, then, the product 54 of the means be divided by the first term 9, we shall have 6 for the fourth term, and the whole proportion will stand $9 : 3=18 : 6$. In general, therefore, if the three first terms are $a : b=c : \ldots\ldots$ we put d for the unknown fourth letter; and since $ad=bc$, we divide both sides by a, and have $d=\frac{bc}{a}$; so that the fourth term $=\frac{bc}{a}$, or is found by multiplying the second and third terms and dividing the product by the first term. This is the foundation of the celebrated RULE OF THREE in arithmetic, wherein three numbers are given to find a fourth in geometrical proportion, so that the first may be to the second as the third is to the fourth. And here we must note some peculiar circumstances which follow.

759. If in two proportions the first and third terms are the same, as in $a : b=c : d$, and $a : f=c : g$, then the two second and the two fourth terms will also be in geometrical proportion, and $b : d=f : g$. For the first proportion being transformed into $a : c=b : d$, and the second into $a : c=f : g$, the relations $b : d$ and $f : g$ must be equal, since each of them is equal to the relation $a : c$. In numbers, if $5 : 25=3 : 15$, and $5 : 40=3 : 24$, we must have $25 : 40=15 : 24$. But if the two proportions be such that the means of both are the same, then the first terms will be in an inverse proportion to the fourth terms. Thus, if $a : b=c : d$, and $f : b=c : g$, then $a : f=g : d$. In numbers, for example, $24 : 8=9 : 3$, and $6 : 8=9 : 12$, we have $24 : 6=12 : 3$. And the reason is evident, for the first proportion gives $ad=bc$; the second $fg=bc$; therefore $ad=fg$, and $a : f=g : d$, or $a : g :: f : d$.

760. If two proportions are given, a new one may always be produced by separately multiplying the first term of the one by the first term of the other, the second by the second, and so on with respect to the other terms. Thus, $a : b=c : d$ and $e : f=g : h$ will furnish $ae : bf=cg : dh$. For the first gives $ad=bc$, and the second $eh=fg$, we have also $adeh=bcfg$. But $adeh$ is the product of the extremes, and $bcfg$ is the product of the means, in the new proportion. So that the two products are equal, and the proportion is true. Let them, for example, be $8 : 2=20 : 5$ and $6 : 9=14 : 21$; the combination will be $6 \times 8 : 2 \times 9=20 \times 14 : 5 \times 21$, or $48 : 18=280 : 105$.

761. Lastly, if two products are equal, $ad=bc$, the equality may be converted into geometrical proportion, for we shall always have one of the factors of the first product in the same proportion to one of the factors of the second product, as the other factor of the second product is to the other factor of the first product; that is, in the present case, $a : c=b : d$, or $a : b=c : d$. In numbers, $3 \times 8=4 \times 6$; and this proportion may be formed $8 : 4=6 : 3$, or $3 : 4=6 : 8$.

762. We do not think it necessary to pursue the subject here by examples of the use of proportion, without which the occurrences of common life could scarcely be carried on. Its basis is here explained, and the application must be obvious to the readers of this work.

COMPOUND RELATIONS.

763. If we multiply the terms of two or more relations, antecedents by antecedents, and consequents by consequents, *compound relations* are obtained; that is, the relation between the two products is compounded of the relations given. Thus the relations $a : b$, $c : d$, $e : f$, give the compound relation $ace : bdf$. Each of these three ratios is said to be one of the *roots* of the compound ratio.

764. As a relation continues the same if both its terms are divided by the same number, in order to abridge it, we may greatly facilitate the above composition by observing whether among the first terms some are not found having common divisors with some of the second terms: for if so, those terms are destroyed, and the quotient arising from the division by that common divisor substituted, of which the following is an example. Let the relations given be $12 : 25$, $28 : 33$, and $55 : 56$.

$$\begin{array}{rcl} 2,\ \cancel{4},\ \cancel{12} & : & \cancel{25},\ 5 \\ \cancel{28} & : & \cancel{33}.\ \cancel{11} \\ \cancel{11},\ \cancel{55} & : & \cancel{56},\ \cancel{2} \\ \hline 2 & : & 5 \end{array}$$

Whence we see that $2 : 5$ is the compound relation required.

765. The same operation is performed if we are calculating by letters; and a remarkable case occurs, when each antecedent is equal to the consequent in the preceding relation: thus, if the given relations are

$$\begin{array}{c} a : b, \\ b : c, \\ c : d, \\ d : e, \\ e : a, \end{array}$$

The compound relation is 1 : 1.

766. We may perceive the utility of these principles by applying them, for instance, to the relation between two rectangular fields, which is compounded of the relations of the lengths and breadths. Let one of them, A, be 500 ft. long and 60 ft. wide, and the other, B, be 360 ft. long and 60 ft. broad; then the relation of the lengths is 500 : 360; that of the breadths 60 : 100. Thus we have

$$\begin{array}{rcl} 5, \cancel{500} & : & \cancel{360}, 6 \\ \cancel{60} & : & \cancel{100} \\ \hline 5 & : & 6 \end{array}$$

Whence the field A is to the field B as 5 to 6.

767. So, again, if we wish to compare two rooms with respect to their space or contents, we are to recollect that here the relation between them is compounded of three relations, namely, that of the lengths, that of the breadths, and that of the heights. Let the room A be 36 ft. long, 16 ft. broad, and 14 ft. high; and the room B be 42 ft. long, 24 ft. broad, and 10 ft. high; we have the relations as follow: —

$$\begin{array}{lrcl} & \text{A} & & \text{B} \\ \text{For the length} & \cancel{6}, \cancel{36} & : & \cancel{42}, \cancel{7} \\ \text{For the breadth} & 2, \cancel{4}, \cancel{16} & : & \cancel{24}, \cancel{4} \\ \text{For the height} & 2, \cancel{14} & : & \cancel{10}, 5 \\ \hline & 4 & : & 5 \end{array}$$

So that the capacity of the room A is to that of the room B as 4 to 5.

768. When the relations thus compounded are equal, multiplicate relations result; namely, two equal relations give a *duplicate ratio* or *ratio of the squares*. Three equal relations produce the *triplicate ratio*, or *ratio of the cubes*, and so on. Thus the relations $a : b$ and $a : b$ give the compound relation $aa : bb$; whence we say that the squares are in the duplicate ratio of the roots; and the ratio $a : b$ multiplied thrice, giving the ratio $a^3 : b^3$, shows that the cubes are in the triplicate ratio of the roots.

769. From a knowledge of Geometry, we learn that two circular spaces are in the duplicate relation of their diameters; which means, that they are to each other as the squares of their diameters. Suppose A to be such a space, having a diameter = 45 ft.; B another circular space, whose diameter = 30; then the first space will be to the second as 45 × 45 to 30 × 30, or, compounding the two equal relations,

$$\begin{array}{rcl} 3, \cancel{9}, \cancel{45} & : & \cancel{30}, \cancel{6}, 2 \\ 3, \cancel{9}, \cancel{45} & : & \cancel{30}, \cancel{6}, 2 \\ \hline 9 & : & 4 \end{array}$$

Whence we see the two areas are as 9 to 4.

770. Again, it is known that the solid contents of spheres are in the ratio of the cubes of the diameters. Thus, the diameter of a globe, A, being 1 ft., and the diameter of another globe, B, being 2 ft.; the solid contents of A will be to those of B as $1^3 : 2^3$, or as 1 to 8. If, therefore, the spheres are composed of similar substances, the sphere B will weigh 8 times as much as the sphere A.

771. The ratio of two fractions $\frac{a}{b} : \frac{c}{d}$ may always be expressed in integer numbers, since we have only to multiply the two fractions by *bd* to obtain the ratio $ad : bc$, which is equal to the other; and if *ad* and *bc* have common divisors, the ratio may be reduced to less terms. For instance, $\frac{15}{24} : \frac{25}{36} = 15 \times 36 : 24 \times 25 = 9 : 10$.

772. Suppose we sought the ratio of the fractions $\frac{1}{a}$ and $\frac{1}{b}$, it is evident we should have $\frac{1}{a} : \frac{1}{b} = b : a$, which is expressed by saying that two fractions which have unity for their denominator are in the *reciprocal* or *inverse* ratio of their denominators. So when any two fractions have a common enumerator, for $\frac{c}{a} : \frac{c}{b} = b : a$. When, however, two fractions have their denominators equal, as $\frac{a}{c} : \frac{b}{c}$, they are in the direct ratio of their numerators, that is, as $a : b$. Thus, $\frac{1}{3} : \frac{3}{18} = \frac{6}{18} : \frac{3}{18} = 6 : 3 = 2 : 1$ and $\frac{10}{7} : \frac{15}{7} = 10 : 15$ or $2 : 3$.

773. It is upon the principles here laid down that we are enabled to resolve questions in what is called in books of arithmetic, THE RULE OF FIVE, as, for example, in the following question: — If 25 pence per day be given to a labourer, and it is required to know what must be given to 24 labourers who have worked 50 days, we state it thus: —

1 : 24 masons.
1 : 50 days.
1 : 1200 = 25 (pence) : £125
25
12)30000
20)2500
125

GEOMETRICAL PROGRESSION.

774. When the numbers of a series increase or decrease by becoming a certain number of times greater or less, the series is called a *geometrical progression*, because each term is to the following one in the same geometrical ratio. The number expressing how many times each term is greater than the preceding is called the *exponent*: thus, if the first term = 1 and the exponent = 2, the geometrical progression becomes,

Terms	1	2	3	4	5	6	7	8	9	&c
Progression	1,	2,	4,	8,	16,	32,	64,	128,	256,	&c.

In which the numbers 1, 2, 3, &c. mark the place which each term holds in the progression. Generally, if the first term $=a$ and the exponent $=b$, we have the following geometrical progression —

Terms	1	2	3	4	5	6	7	8		n
Progression	a,	ab,	ab^2,	ab^3,	ab^4,	ab^5,	ab^6,	ab^7	. . .	ab^{n-1}.

Thus, when the progression proceeds to n terms, the last term is $=ab^{n-1}$. If the exponent b be greater than unity, the terms continue to increase; if the exponent $b=1$, the terms are all equal; and, lastly, if the exponent b be less than 1, or a fraction, the terms continually decrease. So if $a=1$ and $b=\frac{1}{2}$, we have the geometrical progression 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, $\frac{1}{128}$, &c., wherein we have for consideration,

FIRST — The first term, which has been called a.
SECOND — The exponent, which has been called b.
THIRD — The number of terms a
FOURTH — The last term, which has been found $=ab^{n-1}$.

Hence, if any three of these be given, the last term may be found by multiplying the $n-1$ power of b, or b^{n-1}, by the first term a.

775. If, therefore, in the geometrical progression 1, 2, 4, 8, &c. the fiftieth term be required, we have $a=1$, $b=2$, and $n=50$, consequently the fiftieth term is $=2^{49}$. Now $2^9=512$, and $2^{10}=1024$. Wherefore the square of $2^{20}=1048576$, and the square of this number or $1099511627776=2^{40}$; and multiplying this value of 2^{40} by 2^9 or 512, we have $2^{49}=562949953421312$.

776. One of the most usual questions which occur relative to geometrical progression is to find the sum of the terms, the mode of doing which we shall now explain. Let the following progression of ten terms be given: —

1, 2, 4, 8, 16, 32, 64, 128, 256, 512.

We will represent the sum by s, that is, $s=1+2+4+8+16+32+64+128+256+512$. Double both sides and we have $2s=2+4+8+16+32+64+128+256+512+1024$. Subtracting from this the progression represented by s we have $s=1024-1=1023$; wherefore the sum required is 1023.

777. Suppose in the same progression the number of terms is undetermined and $=n$, so that the sum in question or $s=1+2+2^2+2^3+2^4 \ldots\ldots 2^{n-1}$. If we multiply by 2 we have $2s=2+2^2+2^3+2^4 \ldots\ldots 2^n$, and subtracting the preceding from the last equation we have $s=2^{n-1}$. Hence we see that the sum required is found by multiplying the last term 2^{n-1} by the exponent 2 in order to have 2^n, and subtracting unity from that product.

778. Suppose, generally, the first term $=a$, the exponent $=b$, the number of terms $=n$, and their sum $=s$, so that

$$s=a+ab+ab^2+ab^3+ab^4+\ \ldots\ldots\ ab^{n-1}.$$

Multiply by b, and we have

$$bs=ab+ab^2+ab^3+ab^4+ab^5+\ \ldots\ldots\ ab^n,$$

and subtracting the first equation, the remainder is $(b-1)s=ab^n-a$, whence is easily deduced the sum required, $s=\frac{ab^n-a}{b-1}$. Whence it follows that the sum of any geometrical progression may be found by multiplying the last term by the exponent of the progression, subtracting the first term from the product and dividing the remainder by the exponent *minus* unity.

779. Let there be a geometrical progression of seven terms, whereof the first $=3$ and the exponent $=2$. Then $a=3$, $b=2$, and $n=7$. The first term will $=3 \times 2^6$, or $3 \times 64 = 192$, and the progression will be

$$3,\ 6,\ 12,\ 24,\ 48,\ 96,\ 192.$$

Multiplying the last term 192 by the exponent 2 we have 384; subtracting the first term the remainder is 381; and dividing this by $b-1$ or by 1, we have 381 for the sum of the whole progression.

780. When the exponent is less than 1, and the terms of the progression consequently diminish, the sum of such a decreasing progression, which would go on to infinity, may nevertheless be accurately expressed. Thus, let the first term $=1$, the exponent $\frac{1}{2}$, and the sum $=s$, so that

$$s = 1 + \tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \tfrac{1}{16} + \tfrac{1}{32} + \tfrac{1}{64}, \text{ \&c.}$$

Multiply by 2, and we have

$$2s = 2 + 1 + \tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \tfrac{1}{16} + \tfrac{1}{32}, \text{ \&c. } \textit{ad infinitum};$$

subtracting the preceding progression the remainder is $s=2$ for the sum of the proposed infinite progression. In general, suppose the first term $=a$ and the exponent of the progression $=\frac{b}{c}$ (a fraction less than 1), and consequently c is greater than b, the sum of the progression will be found thus:

$$\text{Make } s = a + \frac{ab}{c} + \frac{ab^2}{cc} + \frac{ab^3}{c^3} + \frac{ab^4}{c^4}, \text{ \&c.};$$

multiplying by $\frac{b}{c}$ we shall have

$$\frac{b}{c}s = \frac{ab}{c} + \frac{ab^2}{c^2} + \frac{ab^3}{c^3} + \frac{ab^4}{c^4} +, \text{ \&c. } \textit{ad infinitum};$$

subtracting, the remainder is $(1-\frac{b}{c})s=a$. Hence $s=\frac{a}{1-\frac{b}{c}}$. Multiplying both terms of the fraction by c we have $s=\frac{ac}{c-b}$. The sum, therefore, of the progression is found by dividing the first term a by 1 minus the exponent, or by multiplying a by the denominator of the exponent, and dividing the product by the same denominator, diminished by the numerator of the exponent.

781. So are found the sums of progressions whose terms are alternately affected by the signs + and −. For example:

$$s = a - \frac{ab}{c} + \frac{ab^2}{cc} - \frac{ab^3}{c^3} + \frac{ab^4}{c^4} -, \text{ \&c.}$$

Multiplying by $\frac{b}{c}$ we have

$$\frac{b}{c}s = \frac{ab}{c} - \frac{ab^2}{c^2} + \frac{ab^3}{c^3} - \frac{ab^4}{c^4}, \text{ \&c.}$$

Adding to this equation that preceding we obtain $(1+\frac{b}{c})s=a$. Whence the sum required is $s=\frac{a}{1+\frac{b}{c}}$, or $s=\frac{ac}{c+b}$. Thus, if the first term $a=\frac{3}{5}$, and the exponent $=\frac{2}{5}$; that is to say, $b=2$ and $c=5$, we shall have for the sum of the progression $\frac{3}{5}+\frac{6}{25}+\frac{12}{125}+\frac{24}{625}+$, &c. $=1$: for by subtracting the exponent from 1 there remains $\frac{3}{5}$; and by dividing and dividing the first term by that remainder the quotient is 1.

782. Suppose the terms were alternately positive and negative, thus —

$$\tfrac{3}{5} - \tfrac{6}{25} + \tfrac{12}{125} - \tfrac{24}{625}, \text{ \&c.},$$

the sum will be

$$\frac{a}{1+\frac{b}{c}} = \frac{\frac{3}{5}}{\frac{7}{5}} = \tfrac{3}{7}.$$

In the infinite progression,

$$\tfrac{3}{10} + \tfrac{3}{100} + \tfrac{3}{1000} + \tfrac{3}{10000} + \tfrac{3}{100000}, \text{ \&c.}$$

the first term is $\frac{3}{10}$, and the exponent $\frac{1}{10}$. Subtract this last from 1, and the remainder is $\frac{9}{10}$. If we divide the first term by this fraction the quotient is $\frac{1}{3}$ for the sum of the progression; so that by taking only one term of the progression, namely, $\frac{3}{10}$, the error is only $\frac{1}{30}$. But taking two terms, $\frac{3}{10}+\frac{3}{100}=\frac{33}{100}$, there would still be $\frac{1}{300}$ wanting to make the sum $=\frac{1}{3}$.

We shall conclude with another example in the infinite progression: —

$$9 + \tfrac{9}{10} + \tfrac{9}{100} + \tfrac{9}{1000} + \tfrac{9}{10000}, \text{ \&c.}$$

Here the first term is 9 and the exponent $\frac{1}{10}$. Then 1 minus the exponent $=\frac{9}{10}$ and $\frac{9}{\frac{9}{10}}=10$, the sum required. This series is thus expressed by a decimal fraction 9·9999999, &c.

INFINITE DECIMAL FRACTIONS.

783. It has already been seen that decimal fractions are used in logarithmic calculations, in which vulgar fractions would be useless and cumbersome. In other calculations they are of such importance that we shall here dwell upon them, and show how to transform a vulgar fraction into a decimal, and the converse.

784. Generally let it be required to change the fraction $\frac{a}{b}$ into a decimal fraction. Now, as this fraction expresses no more than the quotient of a divided by b, instead of a let us write a·0000000, whose value does not at all differ from a, since it contains neither tenth nor hundredth parts. Let us divide this by b by the common rules of division, taking care to put in the proper place the point which separates the decimals and the integers, and the operation is performed. Let the fraction, for example, be equivalent to $\frac{1}{2}$, the division in decimals will then stand thus: —

$$2)\frac{1{\cdot}0000000}{0{\cdot}5000000}=\tfrac{1}{2}.$$

From this it appears that $\frac{1}{2}=0{\cdot}5000000$ or $0{\cdot}5$; which is sufficiently manifest, since this decimal fraction represents $\frac{5}{10}$, which is the same as $\frac{1}{2}$.

785. Let the given fraction be $\frac{1}{3}$, and we have

$$3)\frac{1{\cdot}0000000}{0{\cdot}3333333}=\tfrac{1}{3}.$$

786. From this it is seen that the decimal fraction equivalent to $\frac{1}{3}$ cannot be discontinued, but that the number 3 is repeated *ad infinitum*. Indeed, it has been already seen, in the preceding article, that the fractions $\frac{3}{10}+\frac{3}{100}+\frac{3}{1000}+\frac{3}{10000}$ added together make $\frac{1}{3}$. In the same way, the decimal fraction which expresses the value of $\frac{2}{3}$ is 0·6666666, evidently the double of $\frac{1}{3}$.

787. Suppose $\frac{1}{4}$ to be the proposed fraction, we have

$$4)\frac{1{\cdot}0000000}{0{\cdot}2500000}=\tfrac{1}{4};$$

so that $\frac{1}{4}=0{\cdot}2500000$ or $0{\cdot}25$. The proof whereof is that $\frac{2}{10}+\frac{5}{100}=\frac{25}{100}=\frac{1}{4}$.

788. In the same way for the fraction $\frac{3}{4}$, we have

$$4)\frac{3{\cdot}0000000}{0{\cdot}7500000}=\tfrac{3}{4}.$$

Thus we see $\frac{3}{4}=0{\cdot}75$, that is, $\frac{7}{10}+\frac{5}{100}=\frac{75}{100}=\frac{3}{4}$.

789. The fraction $\frac{5}{4}$ is changed into a decimal fraction by making

$$4)\frac{5{\cdot}0000000}{1{\cdot}2500000}=\tfrac{5}{4};$$

for $1+\frac{25}{100}=\frac{5}{4}$.

790. So $\frac{1}{5}$ will be found $=0{\cdot}2$, $\frac{2}{5}=0{\cdot}4$, $\frac{3}{5}=0{\cdot}6$, $\frac{4}{5}=0{\cdot}8$, $\frac{5}{5}=1$, $\frac{6}{5}=1{\cdot}2$, &c. In the occurrence of the denominator 7, the decimal fractions become a little more complicated; thus we have $\frac{1}{7}=0{\cdot}142857142857$, &c., in which the six figures are continually repeated. By transforming this decimal fraction into a geometrical progression, we may see that it precisely expresses the value $\frac{1}{7}$, the first term of this progression $=\frac{142857}{1000000}$, and the exponent $=\frac{1}{1000000}$. Hence the sum $=\dfrac{\frac{142857}{1000000}}{1-\frac{1}{1000000}}=\frac{142857}{1000000}$ (multiplying both terms by 10000000) $=\frac{1}{7}$. There is, however, a simpler mode of proving that this decimal fraction is exactly $\frac{1}{7}$, by substituting for its value the letter s, as under: —

$$\begin{array}{rl}
s = & 0{\cdot}142857142857,\ \&c. \\
10s = & 1{\cdot}428571428571,\ \&c. \\
100s = & 14{\cdot}285714285714,\ \&c. \\
1000s = & 142{\cdot}857142857142,\ \&c. \\
10000s = & 1428{\cdot}571428571428,\ \&c. \\
100000s = & 14285{\cdot}714285714285,\ \&c. \\
1000000s = & 142857{\cdot}142857142857,\ \&c. \\
\text{Subtract } s & 0{\cdot}142857142857,\ \&c. \\
\hline
999999s = & 142857
\end{array}$$

Now, dividing by 999999, we shall have $s=\frac{142857}{999999}=\frac{1}{7}$; hence $s=\frac{1}{7}$.

791. The same will be seen by trial upon other fractions whose denominator is 7, the decimal fraction being infinite and six figures continually repeated. The reason is, that in continuing the division, we must return to a remainder which has already been had; and in

that division only 6 different numbers can form the remainder, namely, 1, 2, 3, 4, 5, 6; so that after the sixth division the same figures must return.

792. With the denominator 8 we have the following decimal fraction: $\frac{1}{8}=0{\cdot}125$, $\frac{2}{8}=0{\cdot}25$, $\frac{3}{8}=0{\cdot}375$, $\frac{4}{8}=0{\cdot}5$, $\frac{5}{8}=0{\cdot}625$, $\frac{6}{8}=0{\cdot}75$ $\frac{7}{8}=0{\cdot}875$, &c. With 9 for the denominator, we have $\frac{1}{9}=0{\cdot}11111$, &c.; $\frac{2}{9}=0{\cdot}22222$, &c.; $\frac{3}{9}=0{\cdot}33333$, &c. With 10 for the denominator, we have $\frac{1}{10}=0{\cdot}1$, $\frac{2}{10}=0{\cdot}2$, $\frac{3}{10}=0{\cdot}3$, which, indeed, is manifest from the nature of the thing; as also that $\frac{1}{100}$ must be 0·01, and $\frac{37}{100}=0{\cdot}37$; that $\frac{472}{1000}=0{\cdot}472$, and that $\frac{15}{10000}=0{\cdot}0015$. If the denominator be 11, then $\frac{1}{11}=0{\cdot}0909090$, &c. Suppose we desired to know the value of this decimal fraction, call it s, then

$$\begin{aligned} s &= 0{\cdot}0909090, \text{\&c.} \\ 10s &= 0{\cdot}9090909, \text{\&c.} \\ 100s &= 9{\cdot}0909090, \text{\&c.} \end{aligned}$$

Subtract s, and we have $99\,s=9$; consequently $s=\frac{9}{99}=\frac{1}{11}$: so with $\frac{2}{11}$, &c.

793. There are many of these decimal fractions which are called *recurring*, sometimes with two, and at other times with more, figures. Their values may be found without difficulty. Thus in the case of a single figure constantly repeated, let it be represented by a, so that $s=0{\cdot}aaaaaaa$, we have

$$\begin{aligned} 10s &= a{\cdot}aaaaaaa \\ \text{subtracting}\quad s &= 0{\cdot}aaaaaaa \\ \hline \text{we have}\quad 9s &= a, \text{ so that } s = \frac{a}{9}. \end{aligned}$$

794. In the case of two figures, as ab, we shall find $s=\frac{ab}{99}$. In the case of three figures, as abc, we shall have $s=\frac{abc}{999}$, and so on.

795. So that if a decimal fraction occurs, it is easy to find its value; for instance, of 0·296296, the value will be $\frac{296}{999}=\frac{8}{27}$, which fraction, it may easily be proved, will give again the decimal fraction required.

796. We shall close this section with a curious example of changing into a decimal fraction the vulgar fraction $\frac{1}{1\times2\times3\times4\times5\times6\times7\times8\times9\times10}$, the operation whereof is as follows:—

2)1·0000000000000

3)0·5000000000000

4)0·1666666666666

5)0·0416666666666

6)0·0083333333333

7)0·0013888888888

8)0·0001984126984

9)0·0000248015873

10)0·0000027557319 2

0·0000002755731 9.

CALCULATION OF INTEREST.

797. Interest, or the value of the use of money, is usually expressed *per cent.*, or after the rate per hundred on the principal lent. Thus, if we put out 500 pounds sterling at 5 per cent., it signifies that for every hundred pounds the lender is to receive five pounds per annum during the continuance of the loan. The solution of this question, which is one merely of *simple interest*, is so obvious, that it is unnecessary further to detain the reader upon it; and we therefore pass on to *compound interest*, or interest upon interest, which arises from the principal and interest taken together, as it becomes due at the end of each stated time of payment.

798. In the resolution of this question, we are to consider that 100*l.* at the end of a year becomes 105*l.* Let a = principal. Its amount at the end of the year is found by saying, if 100 gives 105, what will a give; and we answer $\frac{105a}{100}=\frac{21a}{20}$, which may be also expressed $\frac{21}{20}\times a$, or $a+\frac{1}{20}\times a$.

799. Thus, by adding its twentieth part to the original principal, we have the principal at the end of the first year; adding to this last its twentieth, we know the amount of the given principal in two years, and so on. Hence the annual increases to the principal may be easily computed. Suppose, for instance, the principal of 1000*l.* Expressing the values in decimal fractions, it will be worth —

After 1 year - - -	£1050		
	52·5	One year's interest on	£1050.
After 2 years - - -	1102·5		
	55·125	—	1102·5
After 3 years - - -	1157·625		
	57·881	—	1157·625
After 4 years - - -	1215·506		
	60·775	—	1215·506
After 5 years - - -	1276·281 &c.		

The method above exhibited would, however, in calculations for a number of years, become very laborious, and it may be abridged in the following manner.

800. Let the present principal $=a$; now, since a principal of 20*l.* will amount to 21*l.* at the end of a year, the principal a will amount to $\frac{21}{20}\times a$ at the end of that time. At the end of the following year the same principal will amount to $\frac{21^2}{20^2}\times a=(\frac{21}{20})^2\times a$. This principal of two years will, the year after, amount to $(\frac{21}{20})^3\times a$, which will therefore be the principal of three years; increasing in this manner, at the end of four years the principal becomes $(\frac{21}{20})^4\times a$. After a century it will amount to $(\frac{21}{20})^{100}\times a$, and in general $(\frac{21}{20})^n\times a$ is the amount of the principal after n years; a formula serving to determine the amount of principal after any number of years.

801. The interest of 5 per cent., which has been taken in the above calculation, determined the fraction $\frac{21}{20}$. Had the interest been reckoned at 6 per cent. the principal a would at the end of a year be $(\frac{106}{100})\times a$; at the end of two years to $(\frac{106}{100})^2\times a$; and at the end of n years to $(\frac{106}{100})^n\times a$. Again, if the interest be at 4 per cent. the principal a will, after n years, be $(\frac{104}{100})^n\times a$. Now all these formulæ are easily resolved by logarithms; for if, according to the first supposition, the question be $(\frac{21}{20})^n\times a$, this will be $\mathrm{L.}(\frac{21}{20})^n+\mathrm{L.}a$, and as $(\frac{21}{20})^n$ is a power, we have $\mathrm{L.}(\frac{21}{20})^n=n\mathrm{L.}\frac{21}{20}$: so that the logarithm of the principal required is $=n\times\mathrm{L.}\frac{21}{20}+\mathrm{L.}a$, and the logarithm of the fraction $\frac{21}{20}=\mathrm{L.}21-\mathrm{L.}20$.

802. We shall now consider what the principal of 1000*l.* will amount to at compound interest of 5 per cent. at the end of 100 years. Here $n=100$. Hence the logarithm of the principal required will be $=100\mathrm{L.}\frac{21}{20}+\mathrm{L.}1000$, calculated as under:—

$$\begin{array}{rl}
 & \mathrm{L.}21=1{\cdot}3222193\\
\text{Subtracting} & \mathrm{L.}20=1{\cdot}3010300\\
\hline
 & \mathrm{L.}\frac{21}{20}=0{\cdot}0211893\\
 & \text{Multiply by } 100\\
\hline
 & 100\ \mathrm{L.}\frac{21}{20}=2{\cdot}1189300\\
\text{Add} & \mathrm{L.}1000=3{\cdot}0000000\\
\hline
\end{array}$$

$5{\cdot}1189300=$ Logarithm of the principal required; from the characteristic whereof the principal must be a number of six figures, and by the tables it will appear to be 131,501*l.* In the case of a principal of 3452*l.* at 6 per cent. for sixty-four years, we have $a=3452$ and $n=64$. Principal at the end of the first year therefore $=\frac{106}{100}=\frac{53}{50}$. Hence the logarithm of the principal sought $=64\times\mathrm{L.}\frac{53}{50}+\mathrm{L.}3452$, which will be found to amount to 143,763*l.*

803. When the number of years is very great, errors of considerable magnitude may arise from the logarithms not being sufficiently extended in the decimal places; but as our object here is only to show the principle on which these calculations are founded, we do not think it necessary further to pursue that subject.

804. There is another case which now requires our consideration; it is that of not only adding the interest annually to the principal, but increasing it every year by a new sum $=b$. The original principal a would then increase in the following manner:—

After 1 year, $\frac{21}{20}a+b$
After 2 years, $(\frac{21}{20})^2a+\frac{21}{20}b+b$
After 3 years, $(\frac{21}{20})^3a+(\frac{21}{20})^2b+\frac{21}{20}b+b$
After 4 years, $(\frac{21}{20})^4a+(\frac{21}{20})^3b+(\frac{21}{20})^2b+\frac{21}{20}b+b$
After n years, $(\frac{21}{20})^na+(\frac{21}{20})^{n-1}b+(\frac{21}{20})^{n-2}b+\ldots\ldots\frac{21}{20}b+b$

This principal evidently consists of two parts, whereof the first $=(\frac{21}{20})^na$, and the other, taken inversely, forms the series $b+\frac{21}{20}b+(\frac{21}{20})^2b+(\frac{21}{20})^3b+\ldots\ldots(\frac{21}{20})^{n-1}b$. This last series is evidently a geometrical progression, whose exponent $=\frac{21}{20}$. Its sum, therefore, will be found by first multiplying the last term $(\frac{21}{20})^{n-1}b$ by the exponent $\frac{21}{20}$, which gives $(\frac{21}{20})^nb$. Subtract the first term b, and we have the remainder $(\frac{21}{20})^nb-b$; and lastly, dividing by the exponent minus 1, that is, by $\frac{1}{20}$, we have the sum required, $=20(\frac{21}{20})^n b-20b$. Wherefore the principal sought is $(\frac{21}{20})^n a+20(\frac{21}{20})^n b-20b=(\frac{21}{20})^n\times(a+20b)-20b$.

805. To resolve this formula we must separately calculate its first term $(\frac{21}{20})^n\times(a+20b)$, which is $n\text{L}.\ \frac{21}{20}+\text{L}.(a+20b)$, for the number which answers to this logarithm in the tables will be the first term, and if from this we subtract $20b$ we have the principal sought.

806. Suppose a principal of 1000*l.* placed out at 5 per cent. compound interest, and to it there be annually added 100*l.* besides *its* compound interest, and it be required to know to what it will amount at the end of 25 years. Here $a=1000$, $b=100$, $n=25$; and the operation is as follows: —

$$\text{L}.\tfrac{21}{20}=0{\cdot}021189299$$

$$\text{Multiply by 25 we have } 25\text{L}.\tfrac{21}{20}=0{\cdot}5297324750$$
$$\text{L}.(a+20b)=3{\cdot}4771213135$$
$$\overline{=4{\cdot}0068537885}$$

The first part or number which answers to this logarithm is 10159·1*l.*; from which if we subtract $20b=2000$ we find the principal in question to be after 25 years 8159·1*l.*

807. If it be required to know in how many years a principal of 1000*l.* under the above conditions would amount to 1,000,000*l.*; let n be the number of years required, and since $a=1000$, $b=100$, the principal at the end of n years will be $(\frac{21}{20})^n(3000)-2000$, which sum must make 1,000,000*l.*; whence results this equation: —

$$3000\,(\tfrac{21}{20})^n-2000=1000000$$

$$\text{Adding to both sides 2000 we have } 3000\,(\tfrac{21}{20})^n=1002000$$
$$\text{Dividing both sides by 3000 we have } (\tfrac{21}{20})=334$$

Using logarithms we have $n\text{L}.\frac{21}{20}=\text{L}.334$, and dividing by $\text{L}.\frac{21}{20}$, we obtain $n=\frac{\text{L}.334}{\text{L}.\frac{21}{20}}$. Now $\text{L}.334=2{\cdot}5237465$ and $\text{L}.\frac{21}{20}=0{\cdot}0211893$, wherefore $n=\frac{2{\cdot}5237465}{0{\cdot}0211893}$. If, lastly, the two terms of this fraction be multiplied by 10000000, we shall have $n=\frac{2{\cdot}5237465}{211893}$, equal to one hundred and nineteen years one month and seven days, which is the time wherein the principal of 1000*l.* will be increased to 1,000,000*l.* In the case of an annual decrease instead of increase of the capital by a certan sum, we shall have the following gradations as the values of a, year after year, the interest being at 5 per cent., and, representing by b the sum annually abstracted from the principal,

After 1 year it would be $\frac{21}{20}a-b$
After 2 years — $(\frac{21}{20})^2a-\frac{21}{20}b-b$
After 3 years — $(\frac{21}{20})\,a-(\frac{21}{20})^2b-\frac{21}{20}b-b$
After n years — $(\frac{21}{20})^n a-(\frac{21}{20})^{n-1}b-(\frac{21}{20})^{n-2}b\ \ldots\ldots-(\frac{21}{20})b-b.$

This principal evidently consists of two parts, one whereof is $(\frac{21}{20})^n a$, and the other to be subtracted therefrom, taking the terms inversely, forms a geometrical progression, as follows: —

$$b+(\tfrac{21}{20})b+(\tfrac{21}{20})^2b+(\tfrac{21}{20})^3b+\ \ldots\ldots\ (\tfrac{21}{20})^{n-1}b$$

The sum of this progression has already been found $=20\,(\frac{21}{20})^n b-20b$; if, therefore, this be subtracted from $(\frac{21}{20})^n a$, we have the principal required after n years $=(\frac{21}{20})^n(a-20b)+20b$.

808. For a less period than a year, the exponent n becomes a fraction; for example, 1 day $=\frac{1}{365}$, 2 days $=\frac{2}{365}$, and so on. It often happens that we wish to know the present value of a sum of money payable at the end of *a* number of years. Thus, as 20 pounds in ready money amount in a twelvemonth to 21 pounds, so, reciprocally, 21 pounds payable at the end of a year can be worth only 20 pounds. Therefore, if a be a sum payable at the end of a year, the present value of it is $\frac{20}{21}a$. Hence, to find the present value of a principal a at the end of a year, we must multiply by $\frac{20}{21}$; to find its present value at the end of two years, it must be multiplied by $(\frac{20}{21})^2a$; and, in general, its value n years before the time of payment will be expressed by $(\frac{20}{21})^n a$.

809. Thus, suppose a rent of 100*l.* receivable for 5 years, reckoning interest at 5 per cent., if we would know its value in present money, we have

For £100 due after 1 year, the present value is		£95·239
after 2 years	—	90·704
after 3 years	—	86·385
after 4 years	—	82·272
after 5 years	—	78·355
Sum of the five terms		£432·955

So that in present money, the value is 432*l.* 19*s.* 1*d.*

810. But for a great number of years such a calculation would become laborious. It may be facilitated as follows: — Let the annual rent $=a$, commencing directly and con-

tinuing n years, it will be worth $a+(\frac{20}{21})a+(\frac{20}{21})^2a+(\frac{20}{21})^3a+(\frac{20}{21})^4a \ldots . +(\frac{20}{21})^na$, which is a geometrical progression whose sum is to be found. We have therefore only to multiply the last term by the exponent, the product whereof is $(\frac{20}{21})^{n+1}a$, then subtract the first term, and the remainder is $(\frac{20}{21})^{n+}\ a-a$. Lastly, dividing by the exponent minus 1, that is, $-\frac{1}{21}$, or, which is the same, multiplying by -21, we have the sum required, $=-21(\frac{20}{21})^{n+1}a+21a$, or $21a-21(\frac{20}{21})^{n+1}a$, the value of which second term is easily calculated by logarithms.

SOLUTION OF PROBLEMS.

811. The object of algebra, as well as of mathematics generally, being the determination of quantities which were before unknown, this is obtained by an attentive consideration of the conditions given, which are always expressed in known numbers.

812. When a question is to be resolved, the numbers sought are usually represented by the last letters of the alphabet, and the object is then to find, under the conditions, an equality between two quantities. This equality, represented by a formula, is called an *equation*, and enables us to determine the value of the number sought, and thence to resolve the equation. More than one number is often sought, but they are found by equations in the same manner.

813. To illustrate this, let us take the following example: — Twenty persons, men and women, go to a tavern. The men spend 24 shillings, and the women as much; but each man, it appears, has spent 1 shilling more than each woman. What was the number of men and the number of the women?

Let the number of the men $=x$;
That of the women then will be $=20-x$.

Now, these x men having spent 24 shillings, each man's share must be $\frac{24}{x}$ shillings.

Again, the $20-x$ women having also spent 24 shillings, the share of each woman is $\frac{24}{20-x}$ shillings.

But we know that each woman's share is 1 shilling less than that of each man; if, therefore, we subtract 1 from each man's share, we must obtain that of each of the women; consequently $\frac{24}{x}-1=\frac{24}{20-x}$.

From this last equation we have to find the value of x. We shall hereafter see that $x=8$, which value will correspond to the equation, for $\frac{24}{8}-1=\frac{24}{12}$, includes the equality $2=2$.

814. It is thus seen that an equation consists of two parts separated by the sign of equality $=$, showing that the two quantities are equal to one another. It is often necessary to submit them to a great number of transformations, in order to deduce the value of the unknown quantity, and these are founded on the following principles: —

That two quantities remain equal, whether we add to them or subtract from them equal quantities.

That the same obtains whether we multiply or divide them by the same number, or extract their roots of the same degree.

And lastly, if we take the logarithms of the quantities, as in the preceding section.

815. The equations most easily resolved are those in which the unknown quantity does not exceed the first power after the terms of the equation have been properly arranged. These are called *simple equations*, or *of the first degree*. If after the reduction and ordering of an equation, the second power of an unknown quantity is still found, it is called an *equation of the second degree*, and is more difficult to resolve. When the cube of the unknown quantity appears in an equation, it is called one of the third degree, and so on.

RESOLUTION OF SIMPLE EQUATIONS, OR OF THE FIRST DEGREE.

816. When the number sought, or unknown quantity represented by x, is such that one side only contains that letter, and the other a known number, as $x=12$, the value of x is already found. The object is therefore to arrive at that form, however complicated the equation may be when first formed.

817. To begin with the simplest cases: suppose we have brought an equation to the form $x+9=16$; inspection alone here shows us that $x=7$; and, in general, if we find $x+a=b$, where a and b express known numbers, we have only to subtract a from both sides to obtain the equation $a=b-a$, which indicates the value of x.

818. If the equation found be $x-a=b$, by adding a to both sides we obtain the value of $x=b+a$.

819. So, if the equation has the form $x-a=aa+1$, by adding we have $x=aa+a+1$.

820. In the equation $a-8a=20-6a$, we find $x=20-6a+8a$, or $x=20+2a$. And in $x+6a=20+3a$, we have $x=20+3a-6a$, or $x=20-3a$.

821. If the original equation has the form $x-a+b=c$, we may begin by adding a to both sides, which gives $x+b=c+a$; and then subtracting b from both sides, we have $x=c+a-b$. Or we might add $+a-b$ to both sides, by which we immediately obtain $x=c+a-b$. So in the following examples: —

If $x-2a+3b=0$, we have $x=2a-3b$.
If $x-3a+2b=25+a+2b$, we have $x=25+4a$.
If $x-9+6a=25+2a$, we have $x=34-4a$.

When the equation found has the form $ax=b$, it is only necessary to divide the two sides by a, and we have $x=\frac{b}{a}$. But when the equation has the form $ax+b-c=d$, the terms that accompany ax must be made to vanish by adding to both sides $-b+c$, and then, dividing the new equation $ax=d-b+c$ by a, we have $x=\frac{d-b+c}{a}$. The same value would have been found by subtracting $+b-c$ from the given equation, for we should have had in the same form $ax=d-b+c$ and $x=\frac{d-b+c}{a}$. Hence,

If $2x+5=17$, we have $2x=12$ and $x=6$.
If $3x-8=7$, we have $3x=15$ and $x=5$.
If $4x-5-3a=15+9a$, we have $4x=20+12a$, consequently $x=5+3a$.

When the equation has the form $\frac{x}{a}=b$, multiply both sides by a, and we have $x=ab$. But if $\frac{x}{a}+b-c=d$, we first make $\frac{x}{a}=d-b+c$, and then $x=(d-b+c)a=ad-ab+ac$.

Let $\frac{1}{2}x-3=4$; then $\frac{1}{2}x=(4+3)7$ and $x=14$.
Let $\frac{1}{3}x-1+2a=3+a$, we have $\frac{1}{3}x=4-a$, and $x=12-3a$.
Let $\frac{x}{a-1}-1=a$, we have $\frac{x}{a-1}=a+1$, and $x=aa-1$.

When we have such an equation as $\frac{ax}{b}=c$, multiply first by b, which gives $ax=bc$, and then dividing by a, we have $x=\frac{bc}{a}$. If $\frac{ax}{b}-c=d$, the equation must first be made to take the form $\frac{ax}{b}=d+c$; after which, multiplying by b, we have $ax=bd+bc$, and then $x=\frac{bd+bc}{a}$.

Let $\frac{2}{3}x-4=1$, we have $\frac{2}{3}x=5$ and $2x=15$; whence $x=\frac{15}{2}$, or $7\frac{1}{2}$.
If $\frac{3}{4}x+\frac{1}{2}=5$, we have $\frac{3}{4}x=5-\frac{1}{2}=\frac{9}{2}$; whence $3x=18$, and $x=6$.

In the case of two or more terms containing the letter x either on one or both sides of the equation, the process is as follows: —

822. *First.* If they are on the same side, as in the equation $x+\frac{1}{2}x+5=11$, we have $x+\frac{1}{2}x=6$, or $3x=12$; and, lastly, $x=4$.

Let $x+\frac{1}{3}x+\frac{1}{2}x=44$, to find the value of x. Multiplying by 3 we have $4x+\frac{3}{2}x=132$. Multiply both sides by 2, and we have $11x=264$; whence $x=24$. This might have been effected more shortly by beginning with the reduction of the three terms which contain x to the single term $\frac{11}{6}x$, and then dividing the equation $\frac{11}{6}x=44$ by 11, we should have had $\frac{1}{6}x=4$, whence $x=24$.

Generally, let $ax-bx+cx=d$. It is the same as $(a-b+c)x=d$, whence $x=\frac{d}{a-b+c}$.

823. *Second.* If there be terms containing x on both sides of the equation, they must be made to vanish from that side in which it can most easily be done, that is to say, in which there are fewest of them; thus, in the equation $3x+2=x+10$, x must be first subtracted from both sides, which gives $2x+2=10$; whence $2x=8$, and $x=4$.

Let $x+4=20-x$, it is evident that $2x+4=20$, and thence $2x=16$, and $x=8$.
Let $x+8=32-3x$, we have $4x+8=32$, then $4x=24$, and $x=6$.
Let $15-x=20-2x$, we have then $15+x=20$, and $x=5$.
Let $1+x=5-\frac{1}{2}x$, we have $1+\frac{3}{2}x=5$, and $\frac{3}{2}x=4$; $3x=8$; and, lastly, $x=\frac{8}{3}=2\frac{2}{3}$.
If $\frac{1}{2}-\frac{1}{3}x=\frac{1}{3}-\frac{1}{4}x$, we must add $\frac{1}{3}x$, which gives $\frac{1}{2}=\frac{1}{3}+\frac{1}{12}x$; subtracting $\frac{1}{3}$, there will remain $\frac{1}{12}x=\frac{1}{6}$, and multiplying by 12, we have $x=2$.

If an equation occurs wherein the unknown number x is a denominator, we must make the fraction vanish by multiplying the whole equation by that denominator. Thus in the equation $\frac{100}{x}-8=12$, we must first add 8, and we have $\frac{100}{x}=20$; then, multiplying by x, we have $100=20x$, and dividing by 20, $x=5$,

Let $\frac{5x+3}{x-1}=7$. Multiplying by $x-1$, we have $5x+3=7x-7$.

Subtracting $5x$, there remains $3=2x-7$. Adding 7, we have $2x=10$; whence $x=5$.

Radical signs are not unfrequently found in equations of the first degree. For example, a number x below 100 is required such that the square root of $100-x=8$, or $\sqrt{(100-x)}=8$; the square of both sides is $100-x=64$; adding x we have $100=64+x$, whence we have $x=100-64=36$.

824. The unknown number x is sometimes found in the exponents; in this case, recourse must be had to logarithms. Thus $2^x=512$; taking the logarithms on both sides we have $x\mathrm{L}.2=\mathrm{L}.512$, and dividing by L.2, we find $x=\frac{\mathrm{L}.512}{\mathrm{L}.2}$. We shall here subjoin a few examples of the resolutions of simple equations.

(1.) Divide 7 into two such parts that the greater may exceed the less by 3.

Let the greater part $=x$,
The less will be $=7-x$.
So that $x=7-x+3$, or $x=10-x$.
Adding x, we have $2x=10$, and dividing by 2, $x=5$.
The greater part is 5, and the less is 2.

(2.) Divide the number 1600 into three such parts that the greatest shall be 200 more than the second, and the second 100 more than the third.

Let the third part $=x$, then the second will be $=x+100$, and the greatest $=x+300$.
These parts, then, make up the number 1600; we have therefore —

$$3x+400=1600;\quad 3x=1200;\quad \text{and } x=400.$$

The third part, therefore, is 400, the second 500, and the greatest 700.

(3.) Divide 32 into two such parts that if the less be divided by 6, and the greater by 5, the two quotients taken together may make 6.

Let the less of the two parts sought $=x$. The greater will be $32-x$.
The first, divided by 6, gives $\frac{x}{6}$; the second, divided by 5, gives $\frac{32-x}{5}$.
Now, $\frac{x}{6}+\frac{32-6}{5}=6$; multiplying them by 5, we have $\frac{5}{6}x+32-x=30$, or $-\frac{1}{6}x+32=30$.
Adding $\frac{1}{6}x$, we have $32=30+\frac{1}{6}x$.
Subtracting 30, there remains $2=\frac{1}{6}x$.
Multiplying by 6, we have $x=12$. Wherefore the lesser part $=12$, the greater $=20$.

(4.) Divide 25 into two such parts that the greater may contain the less 49 times.

Let the less part $=x$, then the greater will be $25-x$.
The latter, divided by the former, ought to give the quotient 49; therefore $\frac{25-x}{x}=49$.
Multiplying by x we have $25-x=49x$. Adding x, $25=50x$.
Dividing by 50, $x=\frac{1}{2}$. Hence the less of the two numbers sought is $\frac{1}{2}$, and the greater $24\frac{1}{2}$.

(5.) To find such a number that if 1 be subtracted from its double, and the remainder be doubled, 2 subtracted, and the remainder divided by 4, the number resulting from these operations shall be 1 less than the number sought.

Suppose the number to be $=x$; the double $=2x$.
Subtracting 1, the remainder is $2x-1$; doubling this, we have $4x-2$.
Subtracting 2, the remainder is $4x-4$; dividing by 4 we have $x-1$, and this must be 1 less than x, so that $x-1=x-1$. But this is what is called an *identical equation*, showing that x is indeterminate, or that any number whatever may be substituted for it.

(6.) What sum is that, into how many equal parts is it divided, and what is the amount of each part, wherein

The first part $=100$, and one tenth of the remainder;
The second part $=200$, and one tenth of the then remainder;
The third part $=300$, and one tenth of the then remainder;
The fourth part $=400$, and one tenth of the then remainder; and so on?

Suppose the total sum $=z$. Then, since all the parts are equal, let each $=x$, by which means the number of parts will be expressed by $\frac{z}{x}$. This being established, the solution is as follows: —

Total sum.	Order of the parts.	Amount of each part.	Differences.
z	First	$x=100+\frac{z-100}{10}$	
$z-x$	Second	$x=200+\frac{z-x-200}{10}$	$100-\frac{x-100}{10}=0$
$z-2x$	Third	$x=300+\frac{z-2x-300}{10}$	$100-\frac{x-100}{10}=0$
$z-3x$	Fourth	$x=400+\frac{z+3x-400}{10}$	$100-\frac{x-100}{10}=0$
$z-4x$	Fifth	$x=500+\frac{z+4x-500}{10}$	$100-\frac{x-100}{10}=0$
$z-5x$	Sixth	$x=600+\frac{z+5x-600}{10}$	and so on.

The differences in the last column are obtained by subtracting each part from that which follows, and all the portions being equal, the differences should be $=0$; and as they are expressed exactly alike, it will be sufficient to make one of them equal to nothing, and we have the equation $100-\frac{x-100}{10}=0$. Multiplying by 10, we have $1000-x-100=0$, or $900-x=0$; consequently $x=900$. From this, therefore, we know that each part is 900; and taking any one of the equations in the third column, the first for example, it becomes, by substituting the value of x, $900=100+\frac{z-100}{10}$, whence the value of z is obtained; for we have $9000=1000+z-100$, or $9000=900+z$; whence $z=8100$, and consequently $\frac{z}{x}=9$. Hence the number 8100, and each part $=900$ and the number of the parts $=9$.

RESOLUTION OF TWO OR MORE EQUATIONS OF THE FIRST DEGREE.

825. It often occurs that we are obliged to introduce two or more unknown quantities into algebraic calculations, and these are represented by the letters x, y, z. If the question is determinate, we arrive at the same number of equations from whence to deduce the unknown quantities. Considering only those equations which contain no powers of an unknown quantity higher than the first, and no products of two or more unknown quantities, it is evident that these equations will have the form $ax+by+cx=d$.

826. Beginning with two equations, we will endeavour to find from them the values of x and y; and that the case may be considered in a general manner, let the two equations be — I. $ax+by=c$; and, II. $fx+gy=h$, in which a, b, c, and f, g, h, are known numbers; it is required from these two equations to obtain the two unknown quantities x and y. The most obvious way of proceeding is to determine from both equations the value of one of the unknown quantities, x for example, and to consider the equality of the two values; for then we obtain an equation in which the unknown quantity y appears by itself, and may be determined by the rules we have already given. Knowing y, we have only to substitute its value in one of the quantities that express x.

827. According to this rule we obtain from the first equation $x=\frac{c-by}{a}$, from the second $x=\frac{h-gy}{f}$. Stating these two values equal to one another, a new equation appears,—

$$\frac{c-by}{a}=\frac{h-gy}{f}.$$

Multiplying by a, the product is $c-by=\frac{ah-agy}{f}$; multiplying by f, the product is $fc-fby=ah-agy$. Adding agy, we have $fc-fby+agy=ah$; subtracting fc, there remains $-fby+agy=ah-fc$; or $(ag-bf)y=ah-fc$; lastly, dividing by $ag-bf$, we have $y=\frac{ah-fc}{ag-bf}$.

828. In order to substitute this value of y in one of those we have found of x, as in the first, when $x=\frac{c-by}{a}$, we shall first have $-by=\frac{abh+bcf}{ag-bf}$; whence $c-by=c.-\frac{abh+bcf}{ag-bf}$, or $c-by=\frac{acg-bcf-abh+bcf}{ag-bf}=\frac{acg-abh}{ag-af}$; and dividing by a, $x=\frac{c-by}{a}=\frac{cg-bh}{ay=bf}$.

829. To illustrate this method, let it be proposed to find two numbers whose sum may be $=15$, and difference $=7$.

Let the greater number $=x$, and the less y; we shall then have,

$$\text{I. } x+y=15, \text{ and II. } x-y=7.$$

The first equation gives $x=15-y$, and the second $x=7+y$; whence there results the new equation $15-y=7+y$. So that $15=7+2y$, $2y=8$, and $y=4$; by which means we find $x=11$. The less number, therefore, is 4, and the greater is 11.

830. When there are three unknown numbers, and as many equations, as, for example, I. $x+y-z=8$; II. $x+z-y=9$; III. $y+z-x=10$; a value of x is to be deduced from each: and from I. we have $x=8+z-y$; from II., $x=9+y-z$; and from III. $x=y+z-10$. Comparing them together, we have the following equations:

$$\text{I. } 8+z-y=9+y-z. \quad \text{II. } 8+z-y=y+z-10.$$

The first gives $2z-2y=1$; the second, $2y=18$, or $y=9$. Substitute this value of y in $2z-2y=$, and we have $2z-18=1$, and $2z=19$, so that $z=9\frac{1}{2}$. We have, therefore, only to determine x, which is found $=8\frac{1}{2}$. The letter z thus vanishes in the last equation, and the value of y is immediately found; otherwise we must have had two equations between z and y to have been resolved by the preceding rule.

831. Suppose we had found the three following equations —

$$\text{I. } 3x+5y-4z=25. \quad \text{II. } 5x-2y+3z=46. \quad \text{III. } 3y+5z-x=62.$$

Deducing from each the value of x, we have

$$\text{I. } x=\frac{25-5y+4z}{3}. \quad \text{II. } x=\frac{46+2y-3z}{5}. \quad \text{III. } x=3y+5z-62.$$

And comparing these three values together, and the third with the first, we have $3y+5z-62=\frac{25-5y+4z}{3}$. Multiplying by 3, $9y+15z-186=25-5y+4z$; so that $9y+15z=211-5y+4z$, and $14y+11z=211$. Comparing the third with the second, we have $3y+5z-62=\frac{46+2y-3z}{5}$, or $46+2y-3z=15y+25z-310$, which, reduced, is $356=13y+28z$. From these two new equations the value of y may be deduced.

$$\text{I. } 211=14y+11z;\ \text{whence } 14y=211-11z, \text{ and } y=\frac{211-11z}{14}.$$

$$\text{II. } 356=13y+28z;\ \text{whence } 13y=356-28z, \text{ and } y=\frac{3\quad 28z}{13}.$$

These two values form the new equation $\frac{211-11z}{14}=\frac{356-28z}{13}$, which becomes $2743-143z=4984-392z$, or $249z=2241$; whence $z=9$. This value being substituted in one of the two equations of y and z, we find $y=8$, and by a similar substitution in one of the three values of x, $x=7$.

832. If more than three unknown quantities are to be determined, and as many equations to be resolved, the same manner must be pursued; but the calculations are often tedious; and it is to be observed that in each particular case means may be resorted to for facilitating the resolution. These consist in introducing, besides the principal unknown quantities, some new one, arbitrarily assumed; such, for instance, as the sum of all the rest. But practice only can teach this; and the architect is in this, and remaining pages of this chapter, as much informed on the subject as his practice is likely ever to require.

RESOLUTION OF PURE QUADRATIC EQUATIONS.

833. If an equation contains the square or second power of the unknown quantity without any of the higher powers, it is said to be of the second degree. An equation containing the third power of the unknown quantity belongs to cubic equations, and its resolution requires particular rules. There are, therefore, only three kinds of terms in an equation of the second degree.

I. The terms which do not contain the unknown quantity at all, or which contain only known numbers.

II. The terms wherein only the first power of the unknown quantity is found.

III. The terms which contain the square, or second power of the unknown quantity.

Thus, x signifying an unknown quantity, and the letters a, b, c, d, &c. being known numbers, the terms of the first kind will have the form a, those of the second kind will have the form bx, and those of the third kind will have the form cxx.

834. It has been already seen that two or more terms of the same kind may be united together and considered as a single term; thus the formula $axx-bxx+cxx$ may be considered as a single term if thus represented $(a-b+c)xx$; since, in fact, $(a-b+c)$ is a known quantity. When such terms are found on both sides the sign $=$, we have seen they may be brought to one side, and then reduced to a single term. For example, in the equation

$$2xx-3x+4=5xx-8x+11;$$

We first subtract $2xx$, and the remainder is

$$-3x+4=3xx-8x+11.$$

Then adding $8x$, we have

$$5x+4=3xx+11.$$

Lastly, subtracting 11, the remainder is $3xx=5x-7$.

835. All the terms may also be brought to one side of the sign $=$, leaving only 0 on the other. Thus, the above equation, remembering to change the signs, will assume this form, $3xx-5x+7=0$. Hence, the following general formula represents all equations of the second degree —

$$axx \pm bx \pm c=0,$$

wherein the sign ± is read plus or minus, and shows that the terms to which it is prefixed may be positive or negative. To this formula all quadratic equations may be reduced. Suppose, for instance, the equation

$$\frac{ax+b}{cx+d}=\frac{ex+f}{gx+h}.$$

The fractions must be first destroyed. Multiplying for this purpose by $cx+d$, we have $ax+b=\frac{cexx+cfx+edx+fd}{gx+h}$; then, by $gx+h$, we have $agxx+bgx+ahx+bh=cexx+cfx+edx+fd$, an equation of the second degree, and one which may be reduced to the three following terms, which are transposed by arrangement in the usual manner: —

$$\begin{array}{rl} 0=agxx & +\,bgx+bh \\ -\,cexx & +\,ahx-fd \\ & -\,cfx \\ & -\,edx. \end{array}$$

This equation is, perhaps, more clearly exhibited in the following form: —

$$0=(ag-ce)xx+(bg+ah-cf-ed)x+bh-fd.$$

836. Equations of the second degree are called *complete* when the three kinds of terms are found in them, and their resolution is more difficult; on which account we shall first consider those in which one of the terms is wanting. If the term xx be not found in the equation, it is not a quadratic, but belongs to those whereof we have already treated. If the term containing known numbers only were wanting, the equation would have the form $axx \pm bx=0$, which, being divisible by x, may be reduced to $ax \pm b=0$, which, also, is a simple equation, not belonging to the present class.

837. When the middle term which contains the first power of x is wanting, the equation assumes the form $axx \pm c = 0$, or $axx = \mp c$, as the sign of c is positive or negative. Such an equation is called a *pure* equation of the second degree, since its resolution is without difficulty, for we have only to divide by a, which gives $xx = \frac{c}{a}$; and, taking the square root of both sides, we have $x = \sqrt{\frac{c}{a}}$, which resolves the equation.

838. Three cases are however to be considered; I. when $\frac{c}{a}$ is a square number (whereof, therefore, the root can be assigned) we obtain for the value of x a rational number, either integer or fractional. Thus, $xx = 144$ gives $x = 12$; and $xx = \frac{9}{16}$ gives $x\frac{3}{4}$. II. When $\frac{c}{a}$ is not a square, in which case the sign $\sqrt{}$ must be used. If, for example, $xx = 12x = \sqrt{12}$, the value whereof may be determined by approximation, as heretofore shown. III. When $\frac{c}{a}$ becomes a negative number, then the value of x is altogether impossible and imaginary; this result, indeed, proves the question, that such an equation is in itself impossible.

839. It must be here observed, that whenever the extraction of the square root is required the root has two values, the one negative, the other positive. Take the equation $xx = 49$, the value of x is as well -7 as $+7$, which is expressed by ± 7. Hence all these questions admit of a double answer; but it will easily be perceived that there are many cases in which a negative value cannot exist.

840. In such equations as $axx = bx$, where the known quantity c is wanting, two values of x may exist, though dividing by x we only find one. Thus, in the equation $xx = 3x$, wherein a value of x is required, such that xx may become $= 3x$. This is done by supposing $x = 3$, a value found by dividing the equation by x. Besides this value, however, there is another equally satisfactory, namely, $x = 0$, for then $xx = 0$, and $3x = 0$. Thus equations of the second degree admit of two solutions, whilst simple equations admit only of one.

841. We here submit three examples for the illustration of pure equations of the second degree.

I. Find a number the half whereof multiplied by the third produces 24.

Let the number $= x$. $\frac{1}{2}x$ multiplied by $\frac{1}{3}x$ must produce 24. Therefore $\frac{1}{6}xx = 24$.

Multiplying by 6 we have $xx = 144$, and the root extracted gives $x = \pm 12$. We put ± 12; for if $x = +12$, we have $\frac{1}{2}x = 6$ and $\frac{1}{3}x = 4$, and the product of these quantities is 24. If $x = -12$, we have $\frac{1}{2}x = -6$, and $\frac{1}{3}x = -4$; the product of which is likewise 24.

II. Find a number such that by adding 5 to it and subtracting 5 from it the product of the sum by the difference would be 96.

Let the number be x. Then $x + 5$ multiplied by $x - 5$ must give 96. Therefore $xx - 25 = 96$.

Adding 25 we have $xx = 121$, and extracting the root we have $x = 11$.

Thus $x + 5 = 16$, and $x - 5 = 6$, and lastly, $6 \times 16 = 96$.

III. Find a number such that by adding it to 10 and subtracting it from 10 the sum multiplied by the remainder or difference will give 51.

Let the number $= x$. Then $10 + x$ multiplied by $10 - x$ must make 51. So that $100 - xx = 51$.

Adding xx, and subtracting 51, we have $xx = 49$; the square whereof gives $x = 7$.

RESOLUTION OF MIXED EQUATIONS OF THE SECOND DEGREE.

842. If three kinds of terms are found in an equation of the second degree, namely, — I. That which contains the square of the unknown quantity, as axx; II. That in which the unknown quantity is only known in the first power, as bx; III. The kind of terms composed of known quantities only, — such an equation is said to be *mixed* or complete; since two or more terms of the same kind may be brought into one, and all the terms may be brought to one side of the sign $=$. The general form of a mixed equation of the second degree will be

$$axx \mp bx \mp c = 0.$$

And we now propose to show how the value of x may be derived from such an equation; which may be done in two ways.

843. Such an equation may be by division reduced to such a form that the first term may contain only the square xx of the unknown quantity x. Leaving the second term on the same side with x, we will transpose the known term to the other side of the sign $=$. Thus the equation assumes the form $xx \pm px = \pm q$, in which p and q represent any known numbers, positive or negative; and all we have to do is to find the true value of x. Now if $xx + px$ were a real square, no difficulty would attend the solution; because it would only be required to take the square root on both sides. It is, however, evident that $xx + px$ cannot be a square; for we have already seen that if a root consists of two terms, for example $x + n$, its square must contain three terms, namely, twice the product of the two parts, besides the square of each part; that is, the square of $x + n$ is $xx + 2nx + nn$. Having,

then, already on one side $xx+px$, we may consider xx as the square of the first part of the root, and in this case px must represent twice the product of the first part of the root by the second part, whence the second part must be $\frac{1}{2}p$; and indeed the square of $x+\frac{1}{2}p$ is found to be $xx+px+\frac{1}{4}pp$. Now this last being a real square, which has for its root $x+\frac{1}{2}p$, if we resume the equation $xx+px=q$, we have only to add $\frac{1}{4}pp$ to both sides, and we obtain $xx+px+\frac{1}{4}pp=q+\frac{1}{4}pp$, the first side being a square and the other containing only known quantities. Taking, therefore, the square root of both sides, we find $x+\frac{1}{2}p=\sqrt{(\frac{1}{4}pp+q)}$; and subtracting $\frac{1}{2}p$, we obtain $x=-\frac{1}{2}p+\sqrt{\frac{1}{4}pp+q}$; and as every square root is positive or negative, we shall have for x two values, thus expressed—

$$x=-\tfrac{1}{2}p\pm\sqrt{\tfrac{1}{4}pp+q}.$$

This formula contains the rule whereby all quadratic equations may be resolved, and it should be well remembered, so that it may not be necessary to repeat it. The equation may be always arranged in such a manner that the pure square xx may be found on one side, and the above equation have the form $xx=-px+q$, where it is evident that $x=-\frac{1}{2}\pm\sqrt{\frac{1}{4}pp+q}$.

844. The general rule deduced, therefore, to resolve the equation $xx=-px+q$, depends upon the consideration that the unknown quantity x is equal to half the coefficient or multiplier of x on the other side of the equation, *plus* or *minus* the square root of the square of this number, and the known quantity which forms the third term of the equation.

845. Thus, having the equation $xx=6x+7$, we should immediately say that $x=3\pm\sqrt{9+7}=3\pm4$, when we have for values of x, I. $x=7$; II. $x=-1$. So, also, the equation $xx=10x-9$ would give $x=5\pm\sqrt{25-9}=5\pm4$; that is, the two values of x are 9 and 1. The rule will be better understood by the arrangement under the following cases:—

I. Let p be an even number, and the equation such that $xx=2px+q$, we shall, in that case, have $x=p\pm\sqrt{pp+q}$.

II. Let p be an odd number, and the equation $xx=px+q$; we shall here have $x=p\pm\sqrt{\frac{1}{4}pp+q}$; and since $\frac{1}{4}pp+q=\frac{pp+4q}{4}$, we may extract the square root of the denominator, and write $x=\frac{1}{2}p\pm\frac{\sqrt{pp+4q}}{2}=\frac{p\pm\sqrt{pp+4q}}{2}$.

III. Lastly, if p be a fraction, the equation may be resolved in the following manner: Let it be $axx=bx+c$, or $xx=\frac{bx}{a}+\frac{c}{a}$, and we shall have by the rule $x=\frac{b}{2a}\pm\sqrt{\frac{bb}{4aa}+\frac{c}{a}}$. Now $\frac{bb}{4aa}+\frac{c}{a}=\frac{bb+4ac}{4aa}$, the denominator of which is a square, so that $x=\frac{b\pm\sqrt{bb+4ac}}{2a}$.

The other method of resolving mixed quadratic equations is to transform them into pure equations, which is effected by substitution; thus, in the equation $xx=px+q$, we write another unknown quantity y, instead of the unknown quantity x, such that $x=y+\frac{1}{2}p$, by which, when y is found, the value of x may be readily determined.

846. Making this substitution of $y+\frac{1}{2}p$ instead of x, we have $xx=yy+py+\frac{1}{4}pp$, and $px=py+\frac{1}{2}pp$; hence our equation becomes $yy+py+\frac{1}{4}pp=py+\frac{1}{2}pp+q$, which is first reduced by subtracting py to $yy+\frac{1}{4}pp=\frac{1}{2}pp+q$; and then by subtracting $\frac{1}{4}pp$ to $yy=\frac{1}{4}pp+q$. This is a pure quadratic equation, which directly gives $y=\pm\sqrt{\frac{1}{4}pp+q}$. And since $x=y+\frac{1}{2}p$, we have $x=\frac{1}{2}p\pm\sqrt{\frac{1}{4}pp+q}$ as before. We shall now illustrate the rule by some examples.

I. What are those two numbers, one whereof exceeds the other by 6, and whose product is 91?

If the less be $=x$, the other is $x+6$, and their product $xx+6x=91$.

Subtracting $6x$, the remainder is $xx=91-6x$, and the rule gives

$$x=-3\pm\sqrt{9+91}=-3\pm10;\text{ so that } x=7,\text{ and } x=-13.$$

The question admits of two solutions: by one, the less number $x=7$, and the greater $x+6=13$; by the other, the less number $x=-13$, and the greater $x+6=-7$.

II. Find a number from whose square if 9 be taken, the remainder is a number as many units greater than 100 as the number sought is less than 23.

Let the number sought $=x$. We know that $xx-9$ exceeds 100 by $xx-109$, and since x is less than 23 by $23-x$, we have the equation $xx-109=23-x$.

Wherefore $xx=-x+132$, and by the rule $x=-\frac{1}{2}\pm\sqrt{\frac{1}{4}+132}-\frac{1}{2}\pm\sqrt{\frac{529}{4}}=-\frac{1}{2}\pm23$.
So that $x=11$, and $x=-12$.

If, then, a positive number be required, the number is 11, the square of which *minus* 9 is 112, and, consequently, greater than 100 by 12, in the same manner as 11 is less than 23 by 12.

III. To find two numbers in a double ratio to each other, such that if we add their sum to their product we may obtain 90.

Let one of the numbers $=x$. Then the other will be $=2x$, their product also $=2xx$. If we add to this $3x$, or their sum, the new sum should make 90.

So that $2xx+3x=90$, $2xx=90-3x$, and $xx=-\frac{3}{2}+45$; whence we obtain

$$x=-\tfrac{3}{4}\pm\sqrt{\tfrac{9}{16}+45}=-\tfrac{3}{4}\pm\tfrac{27}{4};$$

consequently $x=6$, or $-7\tfrac{1}{2}$.

IV. To find such a number that if its half be multiplied by its third, and to the product half the number required be added, the result will be 30.

Let the number $=x$. Its half multiplied by its third will make $\frac{1}{6}xx$, so that $\frac{1}{6}xx+\frac{1}{2}x=30$.

Multiply by 6, and we obtain $xx+3x=180$, or $xx=-3x+180$, which gives

$$x=-\tfrac{3}{2}\pm\sqrt{\tfrac{9}{4}+180}=-\tfrac{3}{2}\pm\tfrac{27}{2};$$

consequently x is either $=12$, or -15.

PURE EQUATIONS OF THE THIRD DEGREE.

847. An equation of the third degree is *pure* when the cube of the unknown quantity is equal to a known quantity, and neither the square of the unknown quantity nor the unknown quantity itself is found in the equation.

$x^3=125$; or, more generally, $x^3=a$, $x^3=\frac{a}{b}$ are such equations.

The method of deducing the value of x from such an equation is obvious, for we have only to extract the cube root on both sides. Thus the equation $x^3=125$ gives $x=5$; the equation $x^3=a$ gives $x=\sqrt[3]{a}$; and the equation $x^3=\frac{a}{b}$ gives $x=\sqrt[3]{\frac{a}{b}}$, or $x=\frac{\sqrt[3]{a}}{\sqrt[3]{b}}$. To resolve such equations it is only necessary to know how to extract the cube root of a given number. In this way, however, we obtain only one value for x; but as every equation of the second degree has two values, we have reason to suspect that an equation of the third degree has also more than one value. To investigate this is the object of what follows.

848. Let us, then, take the example $x^3=8$ to find from it the numbers whose cube $=8$. As $x=2$ is such a number, $x^3-8=0$, and must be divisible by $x-2$. The division is as follows: —

$$\begin{array}{l}
x-2)\,x^3-8\,(xx+2x+4\\
\quad\quad\;\, x^3-2xx\\
\hline
\quad\quad\quad\quad 2xx-8\\
\quad\quad\quad\quad 2xx-4x\\
\hline
\quad\quad\quad\quad\quad\quad 4x-8\\
\quad\quad\quad\quad\quad\quad 4x-8\\
\hline
\quad\quad\quad\quad\quad\quad\quad 0
\end{array}$$

Hence it follows that the equation $x^3-8=0$ may be represented by these factors, —

$$(x-2)+(xx+2x+4)=0.$$

The question then is, what number is to be substituted for x in order that $x^3=8$, or that $x^3-8=0$; and it is manifest that the condition is answered by supposing the product just found to be equal to 0. This, however, occurs not only when the first factor $x-2=0$, whence we have $x=2$; but also when the second factor $xx+2x+4=0$. We will therefore make $xx+2x+4=0$, and we shall have $xx=-2x-4$; and thence $x=-1\pm\sqrt{-3}$. From which we learn that besides the case in which $x=2$, which corresponds to the equation $x^3=8$, there are also two other values of x whose cubes are also 8. These are — I. $x=-1+\sqrt{-3}$; and, II. $x=-1-\sqrt{-3}$; which will be evident from cubing them Thus —

$$\begin{array}{lcl}
-1+\sqrt{-3} & \qquad\qquad & -1-\sqrt{-3}\\
-1+\sqrt{-3} & & -1-\sqrt{-3}\\
\hline
1-\sqrt{-3} & & 1+\sqrt{-3}\\
\;\;-\sqrt{-3}-3 & & \;\;+\sqrt{-3}-3\\
\hline
-2-2\sqrt{-3}\ \text{square} & & -2+2\sqrt{-3}\\
-1+\sqrt{-3} & & -1-\;\sqrt{-3}\\
\hline
2+2\sqrt{-3} & & 2-2\sqrt{-3}\\
\;\;-2\sqrt{-3}+6 & & \;\;+2\sqrt{-3}+6\\
\hline
\quad 8\ \text{cube} & & \quad 8\ \text{cube}
\end{array}$$

These values, it is true, are imaginary or impossible, yet they must not be neglected; and, indeed, what has been said applies to every cubic equation, such as $x^3=a$; namely, that besides the value $x=\sqrt[3]{a}$ we shall always find two other values. To abridge the calculation, let us suppose $\sqrt{a}=c$, so that $a=c^3$; the equation will then assume this form, $x^3-c^3=0$, which will be divisible by $x-c$, as under.

$$\begin{array}{rl}
x-c)\,x^3-c^3\,(xx+cx+cc & \\
\underline{x^3-cxx\quad} & \\
cxx-c^3 & \\
\underline{cxx-ccx} & \\
ccx-c^3 & \\
\underline{ccx-c^3} & \\
0 &
\end{array}$$

Consequently the equation in question may be represented by the product $(x-c)\times(xx+cx+cc)=0$, which, in fact, is $=0$, not only when $x-c=0$, or $x=c$, but also when $xx+cx+cc=0$. This expression contains two values of x, inasmuch as it gives $xx=-cx-cc$, and $x=-\frac{c}{2}\pm\sqrt{\frac{cc}{4}-cc}$, or $x=\frac{-c\pm\sqrt{-3cc}}{2}$, that is, $x=\frac{-c\pm\sqrt{-3}}{2}=\frac{-1\pm\sqrt{-3}}{2}\times c$. Now, c having been substituted for $\sqrt[3]{a}$, we conclude that every equation of the third degree of the form $x^3=a$ furnishes three values of x, expressed thus: —

$$\text{I. } x=\sqrt[3]{a}. \quad \text{II. } x=\frac{-1+\sqrt{-3}}{2}\times\sqrt[3]{a}. \quad \text{III. } x=\frac{-1-\sqrt{-3}}{2}\times\sqrt[3]{a}.$$

This shows that every cube root has three different values, but that one only is real, and the other two impossible: and this is the more remarkable, since every square root has two values; and if we were to pursue the subject, (which is not our intention, since the subject is unnecessary for the architect, but if he wishes he must refer to books on the subject,) we should find that every biquadratic root has four different values, and so on with fifth roots, &c. In ordinary calculations only the first of those values is employed, the other two being imaginary. We subjoin some examples: —

I. To find a number whose square multiplied by its fourth part shall produce 432.

Let the number $=x$; then the product of xx multiplied by $\frac{1}{4}x$ must $=432$: that is, $\frac{1}{4}x^3=432$, and $x^3=1728$.

By extracting the cube root we have $x=12$. The number sought, then, is 12 for its square multiplied by its fourth part, or by $3=432$.

II. To find a number whose fourth power divided by its half, with $14\frac{1}{4}$ added to the product, is 100.

Let the number $=x$; its fourth power will be x^4.

Dividing by the half, or $\frac{1}{2}x$, we have $2x^3$; and adding to that $14\frac{1}{4}$, the sum must be 100.

We have, therefore, $2x^3+14\frac{1}{4}=100$; subtracting $14\frac{1}{4}$ the remainder is $2x^3=\frac{343}{4}$.

Dividing by 2 we have $x^3=\frac{343}{8}$, and extracting the cube root we find $x=\frac{7}{2}$.

RESOLUTION OF COMPLETE EQUATIONS OF THE THIRD DEGREE.

849. An equation of the third degree is said to be *complete* when besides the cube of the unknown quantity it contains the unknown quantity itself and its square; so that the general formula for these equations, bringing all the terms to one side, is,

$$ax^3\pm bx^2\pm cx\pm d=0.$$

850. We here propose to show the method of deriving from such equations the values of x, which are also called the *roots* of the equation. There is no doubt, as we have seen in the last section, that such an equation has three roots, as in respect of pure equations of the same degree.

851. First, then, considering the equation $x^3-6xx+11x-6=0$; since an equation of the second degree may be considered as the product of two factors, an equation of the third degree may be represented by the product of three factors, which in the present instance are $(x-1)\times(x-2)\times(x-3)=0$; for by actually multiplying them we obtain the given equation. Thus, $(x-1)\times(x-2)$ gives $xx-3x+2$, and this multiplied by $(x-3)$ gives $x^3-6xx+11x-6$, which are given quantities, and $=0$. This happens when the product $(x-1)\times(x-2)\times(x-3)$ becomes nothing; and as it is sufficient for this purpose that one of the factors $=0$, three different cases may give this result; namely, when $x-1=0$, or $x=1$; secondly, when $x-2=0$, or, $x=2$; and lastly, when $x-3=0$, or, $x=3$. If any number whatever besides one of the above three were substituted for x none of the factors would become $=0$, and consequently the product would no longer $=0$, which proves that the equation can have no other root than those three. If in every other case three factors of such an equation could be assigned in the same manner, we should immediately have three roots. Let us, then, consider more generally these three factors, $x-p$, $x-q$, $x-r$. Seeking their product, the first multiplied by the second gives $xx-(p+q)x+pq$, and this

product multiplied by $x-r$ makes $x^3-(p+q+r)\,xx+(pq+pr+qr)x-pqr$. If this formula must become $=0$, it may happen in three cases: first, when $x-p=0$ or $x=p$; second, when $x-q=0$, or $x=q$; third, when $x-r=0$, or $x=r$. Let us then represent the quantity found by the equation $x^3-axx+bx-c=0$. That its three roots may be, I. $x=p$; II. $x=q$; III. $x=r$, it is evident we must have, 1st. $a=p+q+r$; 2d. $b=pq+pr+qr$; and 3d. $c=pqr$; from which we find that the second term contains the sum of the three roots; that the third term contains the sum of the products of the roots taken two by two; and lastly, that the fourth term consists of the product of all the three roots multiplied together. From this last property is deduced the truth, that an equation of the third degree can have no other rational roots than the divisors of the last term, for that term being the product of the three roots must be divisible by each of them. Hence, to find a root by trial, we immediately see what numbers we are to choose.

852. Let us, for instance, consider the equation $x^3=x+6$, or $x^3-x-6=0$. As this equation can have no other rational roots but numbers which are factors of the last term 6, we have only the numbers 1, 2, 3, 6 to try with, the result whereof will be as follows: —

I. If $x=1$, we have $1-1-6=-6$.
II. If $x=2$, we have $8-2-6=0$.
III. If $x=3$, we have $27-3-6=18$.
IV. If $x=6$, we have $216-6-6=204$.

From which we see that $x=2$ is one of the roots of the given equation; and it will now be easy to find the other two; for $x=2$ being one of the roots, $x-2$ is a factor of the equation, and the other factor is to be sought by means of division, as follows: —

$$\begin{array}{l} x-2)\,x^3-x-6\,(xx+2x+3 \\ \quad\quad\; x^3-2xx \\ \hline \quad\quad\quad\; 2xx-x-6 \\ \quad\quad\quad\; 2xx-4x \\ \hline \quad\quad\quad\quad\quad 3x-6 \\ \quad\quad\quad\quad\quad 3x-6 \\ \hline \quad\quad\quad\quad\quad\quad 0 \end{array}$$

853. Since, then, the formula is represented by the product $(x-2)\times(xx+2x+3)$, it will become $=0$ as well when $x-2=0$ as when $xx+2x+3=0$. This last factor gives $xx=-2x-3$; and consequently $x=-1\pm\sqrt{-2}$. These are the other two roots of the equation, and they are evidently impossible or imaginary.

854. The operation explained is, however, only applicable when the first term x^3 is multiplied by 1, the other terms of the equation having integer coefficients. When this is not the case, a mode must be adopted by which the equation is transformed into another having the condition required, after which the trial mentioned may be made.

855. Let us, for instance, take the equation $x^3-3xx+\frac{11}{4}x-\frac{3}{4}=0$. As there are four parts in it, let us make $x=\frac{y}{2}$; we shall then have $\frac{y^3}{8}-\frac{3yy}{4}+\frac{11y}{8}-\frac{3}{4}=0$, and multiplying by 8 we obtain the equation $y^3-6yy+11y-6=0$; the roots of which are, as we have already seen, $y=1$, $y=2$, $y=3$; whence in the given equation we have, I. $x=\frac{1}{2}$; II. $x=1$; III. $x=\frac{3}{2}$.

Let us take an equation in which the coefficient of the first term is a whole number, different from 1, and whose last term is 1: for instance, $6x^3-11xx+6x-1=0$. Dividing by 6 we have $x^3-\frac{11}{6}xx+x-\frac{1}{6}=0$. The equation may be cleared of fractions by the method just shown. First, supposing $x=\frac{y}{6}$, we shall have $\frac{y^3}{216}-\frac{11yy}{216}+\frac{y}{6}-\frac{1}{6}=0$; and multiplying by 216 the equation becomes $y^3-11yy+36y-36=0$. It would be tedious to try all the divisors of the number 36, and as the last term of the original equation is 1, it is better, in this equation, to suppose $x=\frac{1}{z}$, for we shall then have $\frac{6}{z^3}-\frac{11}{z^2}+\frac{6}{z}-1=0$. Transposing the terms $z^3-6zz+11z-6=0$, the roots are here $z=1$, $z=2$, $z=3$, whence in our equation $x=1$, $x=\frac{1}{2}$, $x=\frac{1}{3}$.

856. It has been heretofore shown that to have all the roots in positive numbers the signs *plus* and *minus* must succeed each other alternately; by this means, the equation takes the form $a^3-axx+bx-c=0$; the signs changing as many times as there are positive roots. Had the three roots been negative, and the three factors $x+p$, $x+q$, $x+r$ had been multiplied together, all the terms would have had the sign *plus*, and the form of the equation would have been $x^3+axx+bx+c=0$, wherein the same signs follow each other three times, that is, the number of the negative roots.

857. From this we may learn that as often as the signs change the equation has positive roots, and when the same signs follow each other the equation has negative roots; and this teaches us whether the divisors of the last term are to be taken affirmatively or negatively, when we wish to make the trial that has been mentioned.

In order to illustrate this, take the equation $x^3+xx-34x+56=0$, wherein the signs change twice and the same sign occurs only once. We see thus that the equation has two positive roots and one negative root; and as the roots must be divisors of the last term 56, they must be included in the numbers ± 1, 2, 4, 7, 8, 14, 28, 56.

858. Let us, then, make $x=2$, and then $8+4-68+56=0$; whence it would appear that $x=2$ is a positive root, and therefore that $x-2$ is a divisor of the equation whereby the other two roots may easily be found; for, dividing by $x-2$, we have

$$\begin{array}{l} x-2)\,x^3+xx-34x+56\,(xx+3x-28 \\ \quad\;\; \underline{x^3-2xx} \\ \qquad\quad \;\; 3xx-34x+56 \\ \qquad\quad \;\; \underline{3xx-\;\;6x} \\ \qquad\qquad\quad -28x+56 \\ \qquad\qquad\quad \underline{-28x+56} \\ \qquad\qquad\qquad\quad 0 \end{array}$$

Making this quotient $xx+3x-28=0$, we find the other two roots, which will be $x=-\frac{3}{2}\pm\sqrt{\frac{9}{4}+28}=-\frac{3}{2}\pm\frac{11}{2}$, that is, $x=4$ or $x=-7$; and considering the root beforehand, $x=2$, we perceive that the equation has two positive roots and one negative. We subjoin some examples.

(I.) What numbers are those whose difference is 12, and whose product multiplied by their sum makes 14560?

Let the less of the two numbers $=x$. The greater will be $x+12$.

Their product $=xx+2x$, multiplied by the sum $2x+12$, gives $2x^3+36xx+144x=14560$.

Divide by 2, and we have $x^3+18xx+72x=7280$.

The last term 7280 is too great to make trial of all the divisors, and it is divisible by 8, wherefore we shall make $x=2y$; because the new equation $8y^3+72yy+144y=7280$, after the substitution, being divided by 8, becomes $y^3+9yy+18y=910$.

To solve this, we only need try the divisors 1, 2, 5, 7. 10, 13, &c. of the number 910.

Now it is evident that the first three are too small. Begin, therefore, by supposing $y=7$, and we find it is one of the roots, for the substitution gives $343+441+126=910$. It follows, then, that $x=14$, and the other roots are found by dividing $y^3+9yy+18y-910$ by $y-7$, as follows: —

$$\begin{array}{l} y-7)\,y^3+9yy+18y-910\,(yy+16y+130 \\ \quad\;\; \underline{y^3-7yy} \\ \qquad\quad 16yy+18y-910 \\ \qquad\quad \underline{16yy-112y} \\ \qquad\qquad\quad 130y-910 \\ \qquad\qquad\quad \underline{130y-910} \\ \qquad\qquad\qquad\;\; 0 \end{array}$$

Supposing this quotient $yy+16y+130=0$, we have $yy=-16y-130$, and thence $y=-8\pm\sqrt{-66}$, which proves that the other two roots are impossible. The numbers sought, therefore, are 14 and 26, the product of which, 364, multiplied by their sum, 40, gives 1456.

(II.) What numbers are those whose difference may be 18, and their sum multiplied by the difference of their cubes may produce the number 275184?

Let the lesser number $=x$. Then the greater will be $x+18$.

The cube of the first will be $=x^3$, and the cube of the second $=x^3+54xx+972x+5832$.

The difference of the cubes $=54xx+972x+5832=54(xx+18x+108)$ multiplied by the sum $2x+18$, or $2(x+9)$, gives the product $108(x^3+27xx+270x+972)=275184$.

Dividing by 108, we have $x^3+27xx+270+972=2548$, or $x^3+27xx+270x=1576$.

The divisors of 1576 are 1, 2, 4, 8, &c. Let us try $x=4$, and we shall find it will satisfy the terms of the equation.

It remains then to divide by $x-4$ to find the other two roots. The quotient will be found to be $xx+31x+394$; making, therefore, $xx=-31x-394$, we find $x=-\frac{31}{2}\pm\sqrt{\frac{961}{4}-\frac{1576}{4}}$, that is, two imaginary roots.

The numbers sought, therefore, are 4 and 22.

(III.) What numbers are those whose difference is 12, and the product of this difference by the sum of their cubes is 102144?

Let the lesser number $=x$; the greater will be $x+12$.

The cube of the first is $=x^3$; the cube of the second is $x^3+36xx+432x+1728$.

The product of the sum of these cubes by the difference 12, is $12(2x^3+36xx+432x+1728)=102144$.

Dividing by 12 and 2, we have $x^3+18xx+216x+864=4256$, or $x^3+18xx+216x=3392=8\times8\times53$.

Suppose $x=2y$, and substituting and dividing by 8, we have $y^3+9yy+54y=8\times53=424$.

The divisors of 424 are 1, 2, 4, 8, 53, &c. 1 and 2 are too small; but making $y=4$ we find $64+144+216=424$; so that $y=4$ and $x=8$, whence we conclude that the two numbers sought are 8 and 20.

859. We shall here close our brief explanation of the principal rules of algebra: they are to be considered more in the light of a preparation for reading and understanding the analytical reasoning and formulæ that we shall hereafter have to use, than as intended to perfect the architectural student in that whereof they treat. He that desires a more intimate acquaintance with the analytical process will of course apply himself to works expressly on the subject. Nevertheless our work could not have been considered complete without that which we have supplied.

860. It remains for us to give, under this chapter, a few applications of the use of decimals, whose nature has already been explained, and to close it with an explanation of duodecimals and the mode of working; to which we now proceed.

DECIMALS.

861. In subsect. 783. *et seq.* the mode of converting vulgar into decimal fractions has been explained. We shall here more particularly apply them to the general subject of our work. Great facilities arise from their application, though there be many fractions of common occurrence which cannot be expressed in decimals without a great number of figures. The following table will show the mode of expressing in decimals the fractional parts of a foot, and will further illustrate the mode of writing down numbers in decimals: —

Feet.	Inches.				
1	1	in vulgar fractions	$1\frac{1}{12}$,	in decimal fractions	1·083333
5	2	. . . .	$5\frac{1}{6}$	. . . .	5·166666
4	3	. . . .	$4\frac{1}{4}$	. . . .	4·25
0	4	. . . .	$\frac{1}{3}$	. . . .	0·333333
3	5	. . . .	$3\frac{5}{12}$	. . . .	3·416666
23	6	. . . .	$23\frac{1}{2}$	. . . .	23·5
548	7	. . . .	$548\frac{7}{12}$	. . . .	548·583333

We may here repeat, that the value of a decimal fraction is not altered by any ciphers on its right hand; thus, ·2500 is of the same value as ·25, but every cipher added between the number and the decimal point decreases the value of the decimal ten times: thus ·25 = $\frac{1}{4}$; ·025 = $\frac{1}{40}$; and ·0025 = $\frac{1}{400}$. The mode of finding the value of recurring decimals has already been given (subsect. 793.); we shall, therefore, proceed to the reduction of a decimal to its corresponding value in inferior denominations. For effecting this, the decimal must be multiplied by the number of parts its integer contains of the denomination to which it is to be reduced, and point off to the left as many figures in the product as there are places in the decimal.

862. Thus, to find the inches and parts equivalent to ·5417 of a foot. Remembering that a foot contains 12 inches, we have —

·5417
12
6·5004 inches; and 1 inch consisting of
12 parts
6·0048 parts; hence ·5417 is equal to 6 inches, and 6·0048 parts.

Again, to find the value in shillings and pence of ·525 of a pound sterling, we have —

·525
20 shillings in a pound
10·500
12
6·000; that is, 10 shillings and 6 pence.

Reciprocally, to find what decimal of a foot are 6 inches 6·0048, we have, first, —

Parts in an inch, 12) 6·0048
Parts in a foot, 12) 6·5004
·5417, the decimal required.

Again, to find what decimal of a pound sterling are ten shillings and sixpence: here we have —

$$\begin{array}{lr} \text{Pence in a shilling} & 12)\ 6\cdot0 \\ \cline{2-2} \text{Shillings in a pound} & 20)10\cdot5 \\ \cline{2-2} & \cdot525, \text{ the decimal required.} \end{array}$$

863. The *addition* of decimal fractions is performed by placing the different numbers with the points directly under each other, and then the addition is made as in whole numbers, observing to place the point in the sum under its place in the numbers.

Example.— Add the numbers 3·5675, 21·375, and 760·00875 together.

$$\begin{array}{r@{\cdot}l} 3 & 5675 \\ 21 & 375 \\ 760 & 00875 \\ \hline 784 & 95125 \end{array}$$

864. The *subtraction* of decimal fractions is performed by placing the fractions with the points directly under each other, and subtracting as in whole numbers.

Example. — From 98·735 take 12·96785.

$$\begin{array}{r@{\cdot}l} 98 & 735 \\ 12 & 96785 \\ \hline 85 & 76715 \end{array}$$

865. The *multiplication* of decimal fractions is performed as in integers, taking care to place the decimal point in the product to the left of as many decimals as are contained in both factors. But if there be not as many places in the product as are contained in both factors, ciphers must be placed to the left to make up the deficiency.

Example. — Multiply 7·335 by 7·5.

$$\begin{array}{r} 7\cdot335 \\ 7\cdot5 \\ \hline 36675 \\ 51345 \\ \hline 55\cdot0125 \end{array}$$

In this case there are three decimal places in the multiplicand, and one in the multiplier. Four decimals must therefore be cut off from the right.

Example. — Multiply ·07325 by ·5235.

$$\begin{array}{r} \cdot07325 \\ \cdot5235 \\ \hline 36625 \\ 21975 \\ 14650 \\ 36625 \\ \hline \cdot038346375 \end{array}$$

Here, because there are five places of decimals in the multiplicand and four in the multiplier, making, in all, nine places, and only eight places come from the multiplication, we must prefix a cipher to make up the nine places.

866. The *division* of decimal fractions is performed as in whole numbers, pointing off from the right of the quotient as many figures for decimals as the dividend has more decimal places than the divisor. If the quotient have not so many figures as the decimals in the dividend exceed those in the divisor, ciphers must be prefixed to the left to make up the deficiency before the point be placed.

Example. — Divide 7·375 by 5·25.

$$\begin{array}{l} 5\cdot25)7\cdot3750000(1\cdot40476 \\ 525 \\ \overline{2125} \\ 2100 \\ \overline{2500} \\ 2100 \\ \overline{4000} \\ 3675 \\ \overline{3250} \\ 3150 \\ \overline{100} \end{array}$$

Now the dividend with the ciphers annexed has seven places of decimals, and the divisor only two; we must therefore cut off five places from the right hand for the decimals of the quotient.

Example. — Divide ·5675 by 72·5.

72·5)·5675000(·007827
5075
6000
5800
2000
1450
5500
5075
425

867. The dividend has, with the ciphers that have been annexed, seven places of decimals, and the divisor only one place; hence we cut off from the right six places for the decimal of the quotient. But on examination it is found that there are only four significant figures obtained; two ciphers must, therefore, be prefixed to the quotient.

DUODECIMALS.

868. Duodecimals are a series of denominations beginning with feet, wherein every inch in the lower denomination makes twelve in that next above it, and they form a series of fractions, whereof the denominations are understood, but not expressed. This method is chiefly in use among measurers of artificers' works, for computing the contents of work. The dimensions are taken in feet, inches, and twelfths of an inch, but not nearer, except in works of the greatest nicety. Feet and inches are marked with their initial letters, but twelfths or seconds by a double accent, thus 2″, and thirds by a triple accent, thus 5‴.

869. To multiply duodecimals together, write down the two dimensions so to be multiplied in such way that the place of feet may stand under the last place of the multiplicand; begin with the right hand denomination of the multiplier, and multiply it by every denomination of the multiplicand, throwing the twelve out of every product, and carrying as many units as there are twelves to the next. Placing the remainders, if any, under the multiplier, so that the like parts in the product may be under like parts of the multiplicand, proceed with every successive figure of the multiplier towards the left, in the same manner, always placing the first figure of the product under the multiplier. Then the sum of these partial products will be the whole product. In duodecimals there will be as many denominations below feet as in both the factors taken together.

Example 1. — Multiply 7 ft. 5 in. by 3 ft. 4 in.

7 : 5
3 : 4
2 : 5 : 8
22 : 3
24 : 8 : 8

Example 2. — Multiply 24 ft. 8 in. 8″ by 3 ft. 7 in.

24 : 8 : 8
3 : 7
14 : 5 : 0 : 8
74 : 2 : 0
88 : 7 : 0 : 8

870. In the first example there is only one place of duodecimals in each factor; there are therefore two places in the product. In the second example there are two places of duodecimals in the multiplicand and one in the multiplier, which make, together, three; there are therefore three denominations in the product. This method of placing the denominations of the factors gives the correct places of the product at once; since like parts of the product stand under like parts of the multiplicand. It also shows the affinity between duodecimals, decimals, and every series or scale of denominations whereof any number divided by the radix of the scale makes one of the next towards the left hand. The consideration is, moreover, useful in discovering readily the kind of product arising from the multiplication of any two single denominations together.

871. When the number of feet runs very high in the factors, it will be much better to write down the product of each multiplication, without casting out the twelve, and add

together those of each denomination beginning on the right, and divide by 12, to carry to the next higher place, then add these, and so on, as often as there are places in the whole product.

Example. — Multiply 262 ft. 5 in. by 54 ft. 8 in.

$$\begin{array}{r}
262 \;:\; 5 \\
54 \;:\; 8 \\
\hline
2099 \;:\; 4 \\
1048 \;:\; 20 \\
13100 \;:\; 250 \\
\hline
197 = \dfrac{2369}{12} \\
\hline
14345 \;:\; 5 \;:\; 4
\end{array}$$

Thus, under inches, the products being set down and added, they amount to 2369, which, divided by twelve, gives 197 to carry to the place of feet, and 5 remainder. Then adding the feet together with the quantity carried. it gives the whole number of feet; while the operation is extremely simple and free from the troubles of either side operations or useless stress on the memory.

872. The division of the foot into 12 parts renders the application of the rules of *practice* very valuable in the computation of duodecimals. The practical rule is to set down the two dimensions one under the other, that is, feet under feet and inches under inches, and multiply each term in the multiplicand by the feet in the multiplier, beginning at the lowest; and, if the numbers be large, put down the inches without carrying 1 for every 12 from inches to feet. Then, instead of multiplying by the inches, take such aliquot parts of the multiplicand as the inches are of a foot; after which add the lines together, carrying 1 for every 12 inches.

Example 1.—Multiply 7 ft. 5 in. by 3 ft. 4 in.

4 in. = $\frac{1}{3}$.

$$\begin{array}{r}
7 : 5 \\
3 : 4 \\
\hline
22 : 3 \\
2 : 5 : 8 \\
\hline
24 : 8 : 8
\end{array}$$

Example 2.—Multiply 262 ft. 5 in. by 54 ft. 8 in.

8 = $\frac{2}{3}$

$$\begin{array}{r}
262 \;:\; 5 \\
54 \;:\; 8 \\
\hline
1048 \;:\; 270 \\
1310 \\
87 \;:\; 5 \;:\; 8 \\
87 \;:\; 5 \;:\; 8 \\
\hline
23 = \dfrac{281}{12} \;:\; 4 \\
\hline
14345 \;:\; 5 \;:\; 4
\end{array}$$

The same examples have been used to show the relative advantage of the two methods.

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873. The abridgment of the labours of practical men is always a matter of importance — being identical with the saving of time which is lost in calculation, and which with the architect is of the utmost importance, when it is recollected what multifarious duties he has to discharge. Hence we doubt not that the following table of squares, cubes, and roots of numbers, up to 1000, will be most acceptable to him. An inspection of the table will at once instruct him in the method of using it. The first column shows the number, the second the square of such number, the third exhibits its cube. In the fourth column is found the square root of the number, and in the fifth its cube root.

Thus, looking to the number 61 in the first column, we find its square to be 3721, its cube 226981, its square root 7·8102497, and its cube root 3·936497.

Again, taking the number 784, we find its square to be 613089, its cube 481890304, its square root 28, and its cube root 9·220872. We presume that we need not further enlarge on instructions on its use.

No.	Square.	Cube.	Square Root.	CubeRoot.	No.	Square.	Cube.	Square Root.	CubeRoot.
1	1	1	1·0	1·0	64	4096	262144	8·0	4·0
2	4	8	1·4142136	1·259921	65	4225	274625	8·0622577	4·020726
3	9	27	1·7320508	1·442250	66	4356	287496	8·1240384	4·041240
4	16	64	2·0	1·587401	67	4489	300763	8·1853528	4·061548
5	25	125	2·2360680	1·709976	68	4624	314432	8·2462113	4·081656
6	36	216	2·4494897	1·817121	69	4761	328509	8·3066239	4·101566
7	49	343	2·6457513	1·912933	70	4900	343000	8·3666003	4·121285
8	64	512	2·8284271	2·0	71	5041	357911	8·4261498	4·140818
9	81	729	3·0	2·080084	72	5184	373248	8·4852814	4·160168
10	100	1000	3·1622777	2·154435	73	5329	389017	8·5440037	4·179339
11	121	1331	3·3166248	2·223980	74	5476	405224	8·6023253	4·198336
12	144	1728	3·4641016	2·289428	75	5625	421875	8·6602540	4·217163
13	169	2197	3·6055513	2·351335	76	5776	438976	8·7177979	4·235824
14	196	2744	3·7416574	2·410142	77	5929	456533	8·7749644	4·254321
15	225	3375	3·8729833	2·466212	78	6084	474552	8·8317609	4·272659
16	256	4096	4·0	2·519842	79	6241	493039	8·8881944	4·290841
17	289	4913	4·1231056	2·571282	80	6400	512000	8·9442719	4·308870
18	324	5832	4·2426407	2·620741	81	6561	531441	9·0	4·326749
19	361	6859	4·3588989	2·668402	82	6724	551368	9·0553851	4·344481
20	400	8000	4·4721360	2·714418	83	6889	571787	9·1104336	4·362071
21	441	9261	4·5825757	2·758923	84	7056	592704	9·1651514	4·379519
22	484	10648	4·6904158	2·802039	85	7225	614125	9·2195445	4·396830
23	529	12167	4·7958315	2·843867	86	7396	636056	9·2736185	4·414005
24	576	13824	4·8989795	2·884499	87	7569	658503	9·3273791	4·431047
25	625	15625	5·0	2·924018	88	7744	681472	9·3808315	4·447960
26	676	17576	5·0990195	2·962496	89	7921	704969	9·4339811	4·464745
27	729	19683	5·1961524	3·0	90	8100	729000	9·4868330	4·481405
28	784	21952	5·2915026	3·036589	91	8281	753571	9·5393920	4·497942
29	841	24389	5·3851648	3·072317	92	8464	778688	9·5916630	4·514357
30	900	27000	5·4772256	3·107232	93	8649	804357	9·6436508	4·530655
31	961	29791	5·5677644	3·141381	94	8836	830584	9·6953597	4·546836
32	1024	32768	5·6568542	3·174802	95	9025	857375	9·7467943	4·562903
33	1089	35937	5·7445626	3·207534	96	9216	884736	9·7979590	4·578857
34	1156	39304	5·8309519	3·239612	97	9409	912673	9·8488578	4·594701
35	1225	42875	5·9160798	3·271066	98	9604	941192	9·8994949	4·610436
36	1296	46656	6·0	3·301927	99	9801	970299	9·9498744	4·626065
37	1369	50653	6·0827625	3·332222	100	10000	1000000	10·0	4·641589
38	1444	54872	6·1644140	3·361975	101	10201	1030301	10·0498756	4·657010
39	1521	59319	6·2449980	3·391211	102	10404	1061208	10·0995049	4·672330
40	1600	64000	6·3245553	3·419952	103	10609	1092727	10·1488916	4·687548
41	1681	68921	6·4031242	3·448217	104	10816	1124864	10·1980390	4·702669
42	1764	74088	6·4807407	3·476027	105	11025	1157625	10·2469508	4·717694
43	1849	79507	6·5574385	3·503398	106	11236	1191016	10·2956301	4·732624
44	1936	85184	6·6332496	3·530348	107	11449	1225043	10·3440804	4·747459
45	2025	91125	6·7082039	3·556893	108	11664	1259712	10·3923048	4·762203
46	2116	97336	6·7823300	3·583048	109	11881	1295029	10·4403065	4·776856
47	2209	103823	6·8556546	3·608826	110	12100	1331000	10·4880885	4·791420
48	2304	110592	6·9282032	3·634241	111	12321	1367631	10·5356538	4·805896
49	2401	117649	7·0	3·659306	112	12544	1404928	10·5830052	4·820284
50	2500	125000	7·0710678	3·684031	113	12769	1442897	10·6301458	4·834588
51	2601	132651	7·1414284	3·708430	114	12996	1481544	10·6770783	4·848808
52	2704	140608	7·2111026	3·732511	115	13225	1520875	10·7238053	4·862944
53	2809	148877	7·2801099	3·756286	116	13456	1560896	10·7703296	4·876999
54	2916	157464	7·3484692	3·779763	117	13689	1601613	10·8166538	4·890973
55	3025	166375	7·4161985	3·802953	118	13924	1643032	10·8627805	4·904868
56	3136	175616	7·4833148	3·825862	119	14161	1685159	10·9087121	4·918685
57	3249	185193	7·5498344	3·848501	120	14400	1728000	10·9544512	4·932424
58	3364	195112	7·6157731	3·870877	121	14641	1771561	11·0	4·946088
59	3481	205379	7·6811457	3·892996	122	14884	1815848	11·0453610	4·959675
60	3600	216000	7·7459667	3·914867	123	15129	1860867	11·0905365	4·973190
61	3721	226981	7·8102497	3·936497	124	15376	1906624	11·1355287	4·986631
62	3844	238328	7·8740079	3·957892	125	15625	1953125	11·1803399	5·0
63	3969	250047	7·9372539	3·979057	126	15876	2000376	11·2249722	5·013298

No.	Square.	Cube.	Square Root.	CubeRoot.	No.	Square.	Cube.	Square Root.	CubeRoot.
127	16129	2048383	11·2694277	5·026526	190	36100	6859000	13·7840488	5·748897
128	16384	2097152	11·3137085	5·039684	191	36481	6967871	13·8202750	5·758965
129	16641	2146689	11·3578167	5·052774	192	36864	7077888	13·8564065	5·768998
130	16900	2197000	11·4017543	5·065797	193	37249	7189057	13·8924440	5·778996
131	17161	2248091	11·4455231	5·078753	194	37636	7301384	13·9283883	5·788960
132	17424	2299968	11·4891253	5·091643	195	38025	7414875	13·9642400	5·798890
133	17689	2352637	11·5325626	5·104469	196	38416	7529536	14·0	5·808786
134	17956	2406104	11·5758369	5·117230	197	38809	7645373	14·0356688	5·818648
135	18225	2460375	11·6189500	5·129928	198	39204	7762392	14·0712473	5·828476
136	18496	2515456	11·6619038	5·142563	199	39601	7880599	14·1067360	5·838272
137	18769	2571353	11·7046999	5·155137	200	40000	8000000	14·1421356	5·848035
138	19044	2628072	11·7473444	5·167649	201	40401	8120601	14·1774469	5·857765
139	19321	2685619	11·7898261	5·180101	202	40804	8242408	14·2126704	5·867464
140	19600	2744000	11·8321596	5·192494	203	41209	8365427	14·2478068	5·877130
141	19881	2803221	11·8743421	5·204828	204	41616	8489664	14·2828569	5·886765
142	20164	2863288	11·9163753	5·217103	205	42025	8615125	14·3178211	5·896368
143	20449	2924207	11·9582607	5·229321	206	42436	8741816	14·3527001	5·905941
144	20736	2985984	12·0	5·241482	207	42849	8869743	14·3874946	5·915481
145	21025	3048625	12·0415946	5·253583	208	43264	8998912	14·4222051	5·924991
146	21316	3112136	12·0830460	5·265637	209	43681	9123329	14·4568323	5·934473
147	21609	3176523	12·1243557	5·277632	210	44100	9261000	14·4913767	5·943911
148	21904	3241792	12·1655251	5·289572	211	44521	9393931	14·5258390	5·953341
149	22201	3307949	12·2065556	5·301459	212	44944	9528128	14·5602198	5·962731
150	22500	3375000	12·2474487	5·313293	213	45369	9663597	14·5945195	5·972091
151	22801	3442951	12·2882057	5·325074	214	45796	9800344	14·6287388	5·981426
152	23104	3511808	12·3288280	5·336803	215	46225	9938375	14·6628783	5·990727
153	23409	3581577	12·3693169	5·348481	216	46656	10077696	14·6969385	6·0
154	23716	3652264	12·4096736	5·360108	217	47089	10218313	14·7309199	6·009244
155	24025	3723875	12·4498996	5·371685	218	47524	10360232	14·7648231	6·018363
156	24336	3796416	12·4899960	5·383213	219	47961	10503459	14·7986486	6·027650
157	24649	3869893	12·5299641	5·394690	220	48400	10648000	14·8323970	6·036811
158	24964	3944312	12·5698051	5·406120	221	48841	10793861	14·8660687	6·045943
159	25281	4019679	12·6095202	5·417501	222	49284	10941048	14·8996644	6·055048
160	25600	4096000	12·6491106	5·428835	223	49729	11089567	14·9331845	6·064126
161	25921	4173281	12·6885775	5·440122	224	50176	11239424	14·9666295	6·073177
162	26244	4251528	12·7279221	5·451362	225	50625	11390625	15·0	6·082201
163	26569	4330747	12·7671453	5·462556	226	51076	11543176	15·0332964	6·091199
164	26896	4410944	12·8062485	5·473703	227	51529	11697083	15·0665192	6·100170
165	27225	4492125	12·8452326	5·484806	228	51984	11852352	15·0996689	6·109115
166	27556	4574296	12·8840987	5·495865	229	52441	12008989	15·1327460	6·118032
167	27889	4657463	12·9228480	5·506879	230	52900	12167000	15·1657509	6·126925
168	28224	4741632	12·9614814	5·517848	231	53361	12326391	15·1986842	6·135792
169	28561	4826809	13·0	5·528775	232	53824	12487168	15·2315462	6·114634
170	28900	4913000	13·0384048	5·539658	233	54289	12649337	15·2643375	6·153449
171	29241	5000211	13·0766968	5·550499	234	54756	12812904	15·2970585	6·162239
172	29584	5088448	13·1148770	5·561298	235	55225	12977875	15·3297097	6·171005
173	29929	5177717	13·1529464	5·572054	236	55696	13144256	15·3622915	6·179747
174	30276	5268024	13·1909060	5·582770	237	56169	13312053	15·3948043	6·188463
175	30625	5359375	13·2287566	5·593445	238	56644	13481272	15·4272486	6·197154
176	30976	5451776	13·2664992	5·604079	239	57121	13651919	15·4596248	6·205821
177	31329	5545233	13·3041347	5·614673	240	57600	13824000	15·4919334	6·214464
178	31684	5639752	13·3416641	5·625226	241	58081	13997521	15·5241747	6·223083
179	32041	5735339	13·3790882	5·635741	242	58564	14172488	15·5563492	6·231678
180	32400	5832000	13·4164079	5·646216	243	59049	14348907	15·5884573	6·240251
181	32761	5929741	13·4536240	5·656652	244	59536	14526784	15·6204994	6·248800
182	33124	6028568	13·4907376	5·667051	245	60025	14706125	15·6524758	6·257324
183	33489	6128487	13·5277493	5·677411	246	60516	14886936	15·6843871	6·265826
184	33856	6229504	13·5646600	5·687734	247	61009	15069223	15·7162336	6·274304
185	34225	6331625	13·6014705	5·698019	248	61504	15252992	15·7480157	6·282760
186	34596	6434856	13·6381817	5·708267	249	62001	15438249	15·7797338	6·291194
187	34969	6539203	13·6747943	5·718479	250	62500	15625000	15·8113883	6·299604
188	35344	6644672	13·7113092	5·728654	251	63001	15813251	15·8429795	6·307992
189	35721	6751269	13·7477271	5·738794	252	63504	16003008	15·8745079	6·316359

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
253	64009	16194277	15·9059737	6·324704	316	99856	31554496	17·7763888	6·811284
254	64516	16387064	15·9373775	6·333025	317	100489	31855013	17·8044938	6·818461
255	65025	16581375	15·9687194	6·341325	318	101124	32157432	17·8325545	6·825624
256	65536	16777216	16·0	6·349602	319	101761	32461759	17·8605711	6·832771
257	66049	16974593	16·0312195	6·357859	320	102400	32768000	17·8885438	6·839903
258	66564	17173512	16·0623784	6·366095	321	103041	33076161	17·9164729	6·847021
259	67081	17373979	16·0934769	6·374310	322	103684	33386248	17·9443584	6·854124
260	67600	17576000	16·1245155	6·382504	323	104329	33698267	17·9722008	6·861211
261	68121	17779581	16·1554944	6·390676	324	104976	34012224	18·0	6·868284
262	68644	17984728	16·1864141	6·398827	325	105625	34328125	18·0277564	6·875343
263	69169	18191447	16·2172747	6·406958	326	106276	34645976	18·0554701	6·882388
264	69696	18399744	16·2480768	6·415068	327	106929	34965783	18·0831413	6·889419
265	70225	18609625	16·2788206	6·423157	328	107584	35287552	18·1107703	6·896435
266	70756	18821096	16·3095064	6·431226	329	108241	35611289	18·1383571	6·903436
267	71289	19034163	16·3401346	6·439275	330	108900	35937000	18·1659021	6·910423
268	71824	19248832	16·3707055	6·447305	331	109561	36264691	18·1934054	6·917396
269	72361	19465109	16·4012195	6·455314	332	110224	36594368	18·2208672	6·924355
270	72900	19683000	16·4316767	6·463304	333	110889	36926037	18·2482876	6·931300
271	73441	19902511	16·4620776	6·471274	334	111556	37259704	18·2756669	6·938232
272	73984	20123648	16·4924225	6·479224	335	112225	37595375	18·3030052	6·945149
273	74529	20346417	16·5227116	6·487153	336	112896	37933056	18·3303028	6·952053
274	75076	20570824	16·5529454	6·495064	337	113569	38272753	18·3575598	6·958943
275	75625	20796875	16·5831240	6·502956	338	114244	38614472	18·3847763	6·965819
276	76176	21024576	16·6132477	6·510829	339	114921	38958219	18·4119526	6·972682
277	76729	21253933	16·6433170	6·518684	340	115600	39304000	18·4390889	6·979532
278	77284	21484952	16·6733320	6·526519	341	116281	39651821	18·4661853	6·986369
279	77841	21717639	16·7032931	6·534335	342	116964	40001688	18·4932420	6·993191
280	78400	21952000	16·7332005	6·542132	343	117649	40353607	18·5202592	7·0
281	78961	22188041	16·7630546	6·549911	344	118336	40707584	18·5472370	7·006796
282	79524	22425768	16·7928556	6·557672	345	119025	41063625	18·5741756	7·013579
283	80089	22665187	16·8226038	6·565415	346	119716	41421736	18·6010752	7·020349
284	80656	22906304	16·8522995	6·573139	347	120409	41781923	18·6279360	7·027106
285	81225	23149125	16·8819430	6·580844	348	121104	42144192	18·6547581	7·033850
286	81796	23393656	16·9115345	6·588531	349	121801	42508549	18·6815417	7·040581
287	82369	23639903	16·9410743	6·596202	350	122500	42875000	18·7082869	7·047208
288	82944	23887872	16·9705627	6·603854	351	123201	43243551	18·7349940	7·054003
289	83521	24137569	17·0	6·611488	352	123904	43614208	18·7616630	7·060696
290	84100	24389000	17·0293864	6·619106	353	124609	43986977	18·7882942	7·067376
291	84681	24642171	17·0587221	6·626705	354	125316	44361864	18·8148877	7·074043
292	85264	94897088	17·0880075	6·634287	355	126025	44738875	18·8414437	7·080698
293	85849	25153757	17·1172428	6·641851	356	126736	45118016	18·8679623	7·087341
294	86436	25412184	17·1464282	6·649399	357	127449	45499293	18·8944436	7·093970
295	87025	25672375	17·1755640	6·656930	358	128164	45882712	18·9208879	7·100588
296	87616	25934336	17·2046505	6·664443	359	128881	46268279	18·9472953	7·107193
297	88209	26198073	17·2336879	6·671940	360	129600	46656000	18·9736660	7·113786
298	88804	26463592	17·2626765	6·679419	361	130321	47045881	19·0	7·120367
299	89401	26730899	17·2916165	6·686882	362	131044	47437928	19·0262976	7·126935
300	90000	27000000	17·3205081	6·694328	363	131769	47832147	19·0525589	7·133492
301	90601	27270901	17·3493516	6·701758	364	132496	48228544	19·0787840	7·140037
302	91204	27543608	17·3781472	6·709172	365	133225	48627125	19·1049732	7·146569
303	91809	27818127	17·4068952	6·716569	366	133956	49027896	19·1311265	7·153090
304	92416	28094464	17·4355958	6·723950	367	134689	49430863	19·1572441	7·159599
305	93025	28372625	17·4642492	6·731316	368	135424	49836032	19·1833261	7·166095
306	93636	28652616	17·4928557	6·738665	369	136161	50243409	19·2093727	7·172580
307	94249	28934443	17·5214155	6·745997	370	136900	50653000	19·2353841	7·179054
308	94864	29218112	17·5499288	6·753313	371	137641	51064811	19·2613603	7·185516
309	95481	29503629	17·5783958	6·760614	372	138384	51478848	19·2873015	7·191966
310	96100	29791000	17·6068169	6·767899	373	139129	51895117	19·3132079	7·198405
311	96721	30080231	17·6351921	6·775168	374	139876	52313624	19·3390796	7·204832
312	97344	30371328	17·6635217	6·782422	375	140625	52734375	19·3649167	7·211247
313	97969	30664297	17·6918060	6·789661	376	141376	53157376	19·3907194	7·217652
314	98596	30959144	17·7200451	6·796884	377	142129	53582633	19·4164878	7·224045
315	99225	31255875	17·7482393	6·804091	378	142884	54010152	19·4422221	7·230427

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
379	143641	54439939	19·4679223	7·236797	442	195364	86350888	21·0237960	7·617411
380	144400	54872000	19·4935887	7·243156	443	196249	86938307	21·0475652	7·623151
381	145161	55306341	19·5192213	7·249504	444	197136	87528384	21·0713075	7·628883
382	145924	55742968	19·5448203	7·255841	445	198025	88121125	21·0950231	7·634606
383	146689	56181887	19·5703858	7·262167	446	198916	88716536	21·1187121	7·640321
384	147456	56623104	19·5959179	7·268482	447	199809	89314623	21·1423745	7·646027
385	148225	57066625	19·6214169	7·274786	448	200704	89915392	21·1660105	7·651725
386	148996	57512456	19·6468827	7·281079	449	201601	90518849	21·1896201	7·657414
387	149769	57960603	19·6723156	7·287362	450	202500	91125000	21·2132034	7·663094
388	150544	58411072	19·6977156	7·293633	451	203401	91733851	21·2367606	7·668766
389	151321	58863869	19·7230829	7·299893	452	204304	92345408	21·2602916	7·674430
390	152100	59319000	19·7484177	7·306143	453	205209	92959677	21·2837967	7·680085
391	152881	59776471	19·7737199	7·312383	454	206116	93576664	21·3072758	7·685732
392	153664	60236288	19·7989899	7·318611	455	207025	94196375	21·3307290	7·691371
393	154449	60698457	19·8242276	7·324829	456	207936	94818816	21·3541565	7·697002
394	155236	61162984	19·8494332	7·331037	457	208849	95443993	21·3775583	7·702624
395	156025	61629875	19·8746069	7·337234	458	209764	96071912	21·4009346	7·708238
396	156816	62099136	19·8997487	7·343420	459	210681	96702579	21·4242853	7·713844
397	157609	62570773	19·9248588	7·349596	460	211600	97336000	21·4476166	7·719442
398	158404	63044792	19·9499373	7·355762	461	212521	97972181	21·4709106	7·725032
399	159201	63521199	19·9749844	7·361917	462	213444	98611128	21·4941853	7·730614
400	160000	64000000	20·0	7·368063	463	214369	99252847	21·5174348	7·736187
401	160801	64481201	20·0249844	7·374198	464	215296	99897344	21·5406592	7·741753
402	161604	64964808	20·0499377	7·380322	465	216225	100544625	21·5638587	7·747310
403	162409	65450827	20·0748599	7·386437	466	217156	101194696	21·5870331	7·752860
404	163216	65939264	20·0997512	7·392542	467	218089	101847563	21·6101828	7·758402
405	164025	66430125	20·1246118	7·398636	468	219024	102503232	21·6333077	7·763936
406	164836	66923416	20·1494417	7·404720	469	219961	103161709	21·6564078	7·769462
407	165649	67419143	20·1742410	7·410794	470	220900	103823000	21·6794834	7·774980
408	166464	67917312	20·1990099	7·416859	471	221841	104487111	21·7025344	7·780490
409	167281	68417929	20·2237484	7·422914	472	222784	105154048	21·7255610	7·785992
410	168100	68921000	20·2484567	7·428958	473	223729	105823817	21·7485632	7·791487
411	168921	69426531	20·2731349	7·434993	474	224676	106496424	21·7715411	7·796974
412	169744	69934528	20·2977831	7·441018	475	225625	107171875	21·7944947	7·802453
413	170569	70444997	20·3224014	7·447033	476	226576	107850176	21·8174242	7·807925
414	171396	70951944	20·3469899	7·453039	477	227529	108531333	21·8403297	7·813389
415	172225	71473375	20·3715488	7·459036	478	228484	109215352	21·8632111	7·818845
416	173056	71991296	20·3960781	7·465022	479	229441	109902239	21·8860686	7·824294
417	173889	72511713	20·4205779	7·470999	480	230400	110592000	21·9089023	7·829735
418	174724	73034632	20·4450483	7·476966	481	231361	111284641	21·9317122	7·835168
419	175561	73560059	20·4694895	7·482924	482	232324	111980168	21·9544984	7·840594
420	176400	74088000	20·4939015	7·488872	483	233289	112678587	21·9772610	7·846013
421	177241	74618461	20·5182845	7·494810	484	234256	113379904	22·0	7·851424
422	178084	75151448	20·5426386	7·500740	485	235225	114084125	22·0227155	7·856828
423	178929	75686967	20·5669638	7·506660	486	236196	114791256	22·0454077	7·862224
424	179776	76225024	20·5912603	7·512571	487	237169	115501303	22·0680765	7·867613
425	180625	76765625	20·6155281	7·518473	488	238144	116214272	22·0907220	7·872994
426	181476	77308776	20·6397674	7·524365	489	239121	116930169	22·1133444	7·878368
427	182329	77854483	20·6639783	7·530248	490	240100	117649000	22·1359436	7·883734
428	183184	78402752	20·6881609	7·536121	491	241081	118370771	22·1585198	7·889094
429	184041	78953589	20·7123152	7·541986	492	242064	119095488	22·1810730	7·894446
430	184900	79507000	20·7364414	7·547841	493	243049	119823157	22·2036033	7·899791
431	185761	80062991	20·7605395	7·553688	494	244036	120553784	22·2261108	7·905129
432	186624	80621568	20·7846097	7·559525	495	245025	121287375	22·2485955	7·910460
433	187489	81182737	20·8086520	7·565353	496	246016	122023936	22·2710575	7·915784
434	188356	81746504	20·8326667	7·571173	497	247009	122763473	22·2934968	7·921100
435	189225	82312875	20·8566536	7·576984	498	248004	123505992	22·3159136	7·926408
436	190096	82881856	20·8806130	7·582786	499	249001	124251499	22·3383079	7·931710
437	190969	83453453	20·9045450	7·588579	500	250000	125000000	22·3606798	7·937005
438	191844	84027672	20·9284495	7·594363	501	251001	125751501	22·3830293	7·942293
439	192721	84604519	20·9523268	7·600138	502	252004	126506008	22·4053565	7·947573
440	193600	85184000	20·9761770	7·605905	503	253009	127263527	22·4276615	7·952847
441	194481	85766121	21·0	7·611662	504	254016	128024064	22·4499443	7·958114

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	CubeRoo
505	255025	128787625	22·4722051	7·963374	568	322624	183250432	23·8327506	8·281635
506	256036	129554216	22·4944438	7·968627	569	323761	184220009	23·8537209	8·286493
507	257049	130323843	22·5166605	7·973873	570	324900	185193000	23·8746728	8·291344
508	258064	131096512	22·5388553	7·979112	571	326041	186169411	23·8956063	8·296190
509	259081	131872229	22·5610283	7·984344	572	327184	187149248	23·9165215	8·301030
510	260100	132651000	22·5831796	7·989569	573	328329	188132517	23·9374184	8·305865
511	261121	133432831	22·6053091	7·994788	574	329476	189119224	23·9582971	8·310694
512	262144	134217728	22·6274170	8·0	575	330625	190109375	23·9791576	8·315517
513	263169	135005697	22·6495033	8·005205	576	331776	191102976	24·0	8·320335
514	264196	135796744	22·6715681	8·010403	577	332929	192100033	24·0208243	8·325147
515	265225	136590875	22·6936114	8·015595	578	334084	193100552	24·0416306	8·329954
516	266256	137388096	22·7156334	8·020779	579	335241	194104539	24·0624188	8·334755
517	267289	138188413	22·7376340	8·025957	580	336400	195112000	24·0831892	8·339551
518	268324	138991832	22·7596134	8·031129	581	337561	196122941	24·1039416	8·344341
519	269361	139798359	22·7815715	8·036293	582	338724	197137368	24·1246762	8·349125
520	270400	140608000	22·8035085	8·041451	583	339889	198155287	24·1453929	8·353904
521	271441	141420761	22·8254244	8·046603	584	341056	199176704	24·1660919	8·358678
522	272484	142236648	22·8473193	8·051748	585	342225	200201625	24·1867732	8·363446
523	273529	143055667	22·8691933	8·056886	586	343396	201230056	24·2074369	8·368209
524	274576	143877824	22·8910463	8·062018	587	344569	202262003	24·2280829	8·372966
525	275625	144703125	22·9128785	8·067143	588	345744	203297472	24·2487113	8·377718
526	276676	145531576	22·9346899	8·072262	589	346921	204336469	24·2693222	8·382465
527	277729	146363183	22·9564806	8·077374	590	348100	205379000	24·2899156	8·387206
528	278784	147197952	22·9782506	8·082480	591	349281	206425071	24·3104916	8·391942
529	279841	148035889	23·0	8·087579	592	350464	207474688	24·3310501	8·396673
530	280900	148877000	23·0217289	8·092672	593	351649	208527857	24·3515913	8·401398
531	281961	149721291	23·0434372	8·097758	594	352836	209584584	24·3721152	8·406118
532	283024	150568768	23·0651252	8·102838	595	354025	210644875	24·3926218	8·410832
533	284089	151419437	23·0867928	8·107912	596	355216	211708736	24·4131112	8·415541
534	285156	152273304	23·1084400	8·112980	597	356409	212776173	24·4335834	8·420245
535	286225	153130375	23·1300670	8·118041	598	357604	213847192	24·4540385	8·424944
536	287296	153990656	23·1516738	8·123096	599	358801	214921799	24·4744765	8·429638
537	288369	154854153	23·1732605	8·128144	600	360000	216000000	24·4948974	8·434327
538	289444	155720872	23·1948270	8·133186	601	361201	217081801	24·5153013	8·439009
539	290521	156590819	23·2163735	8·138223	602	362404	218167208	24·5356883	8·443687
540	291600	157464000	23·2379001	8·143253	603	363609	219256227	24·5560583	8·448360
541	292681	158340421	23·2594067	8·148276	604	364816	220348864	24·5764115	8·453027
542	293764	159220088	23·2808935	8·153293	605	366025	221445125	24·5967478	8·457689
543	294849	160103007	23·3023604	8·158304	606	367236	222545016	24·6170673	8·462347
544	295936	160989184	23·3238076	8·163309	607	368449	223648543	24·6373700	8·466999
545	297025	161878625	23·3452351	8·168308	608	369664	224755712	24·6576560	8·471647
546	298116	162771336	23·3666429	8·173302	609	370881	225866529	24·6779254	8·476289
547	299209	163667323	23·3880311	8·178289	610	372100	226981000	24·6981781	8·480926
548	300304	164566592	23·4093998	8·183269	611	373321	228099131	24·7184142	8·485557
549	301401	165469149	23·4307490	8·188244	612	374544	229220928	24·7386338	8·490184
550	302500	166375000	23·4520788	8·193212	613	375769	230346397	24·7588368	8·494806
551	303601	167284151	23·4733892	8·198175	614	376996	231475544	24·7790234	8·499423
552	304704	168196608	23·4946802	8·203131	615	378225	232608375	24·7991935	8·504034
553	305809	169112377	23·5159520	8·208082	616	379456	233744896	24·8193473	8·508641
554	306916	170031464	23·5372046	8·213027	617	380689	234885113	24·8394847	8·513243
555	308025	170953875	23·5584380	8·217965	618	381924	236029032	24·8596058	8·517840
556	309136	171879616	23·5796522	8·222898	619	383161	237176659	24·8797106	8·522432
557	310249	172808693	23·6008474	8·227825	620	384400	238328000	24·8997992	8·527018
558	311364	173741112	23·6220236	8·232746	621	385641	239483061	24·9198716	8·531600
559	312481	174676879	23·6431808	8·237661	622	386884	240641848	24·9399278	8·536177
560	313600	175616000	23·6643191	8·242570	623	388129	241804367	24·9599679	8·540749
561	314721	176558481	23·6854386	8·247474	624	389376	242970624	24·9799920	8·545317
562	315844	177504328	23·7065392	8·252371	625	390625	244140625	25·0	8·549879
563	316969	178453547	23·7276210	8·257263	626	391876	245314376	25·0199920	8·554437
564	318096	179406144	23·7486842	8·262149	627	393129	246491883	25·0399681	8·558990
565	319225	180362125	23·7697286	8·267029	628	394384	247673152	25·0599282	8·563537
566	320356	181321496	23·7907545	8·271903	629	395641	248858189	25·0798724	8·568080
567	321489	182284263	23·8117618	8·276772	630	396900	250047000	25·0998008	8·572618

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
631	398161	251239591	25·1197134	8·577152	694	481636	334255384	26·3438797	8·853598
632	399424	252435968	25·1396102	8·581680	695	483025	335702375	26·3628527	8·857849
633	400689	253636137	25·1594913	8·586204	696	484416	337153536	26·3818119	8·862095
634	401956	254840104	25·1793566	8·590723	697	485809	338608873	26·4007576	8·866337
635	403225	256047875	25·1992063	8·595238	698	487204	340068392	26·4196896	8·870575
636	404496	257259456	25·2190404	8·599747	699	488601	341532099	26·4386081	8·874809
637	405769	258474853	25·2388589	8·604252	700	490000	343000000	26·4575131	8·879040
638	407044	259694072	25·2586619	8·608752	701	491401	344472101	26·4764046	8·883266
639	408321	260917119	25·2784493	8·613248	702	492804	345948408	26·4952826	8·887488
640	409600	262144000	25·2982213	8·617738	703	494209	347428927	26·5141472	8·891706
641	410881	263374721	25·3179778	8·622224	704	495616	348913664	26·5329983	8·895920
642	412164	264609288	25·3377189	8·626706	705	497025	350402625	26·5518361	8·900130
643	413449	265847707	25·3574447	8·631183	706	498436	351895816	26·5706605	8·904336
644	414736	267089984	25·3771551	8·635655	707	499849	353393243	26·5894716	8·908538
645	416025	268336125	25·3968502	8·640122	708	501264	354894912	26·6082694	8·912736
646	417316	269586136	25·4165301	8·644585	709	502681	356400829	26·6270539	8·916931
647	418609	270840023	25·4361947	8·649043	710	504100	357911000	26·6458252	8·121121
648	419904	272097792	25·4558441	8·653497	711	505521	359425431	26·6645833	8·925307
649	421201	273359449	25·4754784	8·657946	712	506944	360944128	26·6833281	8·929490
650	422500	274625000	25·4950076	8·662301	713	508369	362467097	26·7020598	8·933668
651	423801	275894451	25·5147016	8·666831	714	509796	363994344	26·7207784	8·937843
652	425104	277167808	25·5342907	8·671266	715	511225	365525875	26·7394839	8·942014
653	426409	278445077	25·5538647	8·675697	716	512656	367061696	26·7581763	8·946180
654	427716	279726264	25·5734237	8·680123	717	514089	368601813	26·7768557	8·950343
655	429025	281011375	25·5929678	8·684545	718	515524	370146232	26·7955220	8·954502
656	430336	282300416	25·6124969	8·688963	719	516961	371694959	26·8141754	8·958658
657	431649	283593393	25·6320112	8·693376	720	518400	373248000	26·8328157	8·962809
658	432964	284890312	25·6515107	8·697784	721	519841	374805361	26·8514432	8·966957
659	434281	286191179	25·6709953	8·702188	722	521284	376367048	26·8700577	8·971100
660	435600	287496000	25·6904652	8·706587	723	522729	377933067	26·8886593	8·975240
661	436921	288804781	25·7099203	8·710982	724	524176	379503424	26·9072481	8·979376
662	438244	290117528	25·7203607	8·715373	725	525625	381078125	26·9258240	8·983508
663	439569	291434247	25·7487864	8·719759	726	527076	382657176	26·9443872	8·987637
664	440896	292754944	25·7681975	8.724141	727	528529	384240583	26·9629375	8·991762
665	442225	294079625	25·7875939	8·728518	728	529984	385828352	26·9814751	8·995883
666	443556	295408296	25·8069758	8·732891	729	531441	387420489	27·0	9·0
667	444889	296740963	25·8263431	8·737260	730	532900	389017000	27·0185122	9·004113
668	446224	298077632	25·8456960	8·741624	731	534361	390617891	27·0370117	9·008222
669	447561	299418309	25·8650343	8·745984	732	535824	392223168	27·0554985	9·012328
670	448900	300763000	25·8843582	8·750340	733	537289	393832837	27·0739727	9·016430
671	450241	302111711	25·9036677	8·754691	734	538756	395446904	27·0924344	9·020529
672	451584	303464448	25·9229628	8·759038	735	540225	397065375	27·1108834	9·024623
673	452929	304821217	25·9422435	8·763380	736	541696	398688256	27·1293199	9·028714
674	454276	306182024	25·9615100	8·767719	737	543169	400315553	27·1477439	9·032802
675	455625	307546875	25·9807621	8·772053	738	544644	401947272	27·1661554	9·036885
676	456976	308915776	26·0	8·776382	739	546121	403583419	27·1845544	9·040965
677	458329	310288733	26·0192237	8·780708	740	547600	405224000	27·2029410	9·045041
678	459684	311665752	26·0384331	8·785029	741	549081	406869021	27·2213152	9·049114
679	461041	313046839	26·0576284	8·789346	742	550564	408518488	27·2396769	9·053183
680	462400	314432000	26·0768096	8·793659	743	552049	410172407	27·2580263	9·057248
681	463761	315821241	26·0959767	8·797967	744	553536	411830784	27·2763634	9·061309
682	465124	317214568	26·1151297	8·802272	745	555025	413493625	27·2946881	9·065367
683	466489	318611987	26·1342687	8·806572	746	556516	415160936	27·3130006	9·069422
684	467856	320013504	26·1533937	8·810868	747	558009	416832723	27·3313007	9·073472
685	469225	321419125	26·1725047	8·815159	748	559504	418508992	27·3495887	9·077519
686	470596	322828856	26·1916017	8·819417	749	561001	420189749	27·3678644	9·081563
687	471969	324242703	26·2106848	8·823730	750	562500	421875000	27·3861279	9·085603
688	473344	325660672	26·2297541	8·828009	751	504001	423564751	27·4043792	8·089639
689	474721	327082769	26·2488095	8·832285	752	565504	425259008	27·4226184	9·093672
690	476100	328509000	26·2678511	8·836556	753	567009	426957777	27·4408455	9·097701
691	477481	329939371	26·2868789	8·840822	754	568516	428661064	27·4590604	9·101726
692	478864	331373888	26·3058929	8·845085	755	570025	430368875	27·4772633	9·105748
693	480249	332812557	26·3248932	8·849344	756	571536	432081216	27·4954542	9·109766

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
757	573049	433798093	27·5136330	9·113781	820	672400	551368000	28·6356421	9·359901
758	574564	435519512	27·5317998	9·117793	821	674041	553387661	28·6530976	9·363704
759	576081	437245479	27·5499546	9·121801	822	675684	555412248	28·6705424	9·367505
760	577600	438976000	27·5680975	9·125805	823	677329	557441767	28·6879766	9·371302
761	579121	440711081	27·5862284	9·129806	824	678976	559476224	28·7054002	9·375096
762	580644	442450728	27·6043475	9·133808	825	680625	561515625	28·7228132	9·378887
763	582169	444194947	27·6224546	9·137797	826	682276	563559976	28·7402157	9·382675
764	583696	445943744	27·6405499	9·141788	827	683929	565609283	28·7576077	9·386460
765	585225	447697125	27·6586334	9·145774	828	685584	567663552	28·7749891	9·390241
766	586756	449455096	27·6767050	9·149757	829	687241	569722789	28·7923601	9·394020
767	588289	451217663	27·6947648	9·153737	830	688900	571787000	28·8097206	9·397796
768	589824	452984832	27·7128129	9·157713	831	690561	573856191	28·8270706	9·401569
769	591361	454756609	27·7308492	9·161686	832	692224	575930368	28·8444102	9·405338
770	592900	456533000	27·7488739	9·165656	833	693889	578009537	28·8617394	9·409105
771	594441	458314011	27·7668868	9·169622	834	695556	580093704	28·8790582	9·412869
772	595984	460099648	27·7848880	9·173585	835	697225	582182875	28·8963666	9·416630
773	597529	461889917	27·8028775	9·177544	836	698896	584277056	28·9136646	9·420387
774	599076	463684824	27·8208555	9·181500	837	700569	586376253	28·9309523	9·424141
775	600625	465484375	27·8388218	9·185452	838	702244	588480472	28·9482297	9·427893
776	602176	467288576	27·8567766	9·189401	839	703921	590589719	28·9654967	9·431642
777	603729	469097433	27·8747197	9·193347	840	705600	592704000	28·9827535	9·435388
778	605284	470910952	27·8926514	9·197289	841	707281	594823321	29·0	9·439130
779	606841	472729139	27·9105715	9·201228	842	708964	596947688	29·0172363	9·442870
780	608400	474552000	27·9284801	9·205164	843	710649	599077107	29·0344623	9·446607
781	609961	476379541	27·9463772	9·209096	844	712336	601211584	29·0516781	9·450341
782	611524	478211768	27·9642629	9·213025	845	714025	603351125	29·0688837	9·454071
783	613089	480048687	27·9821372	9·216950	846	715717	605495736	29·0860791	9·457799
784	614656	481890304	28·0	9·220872	847	717409	607645423	29·1032644	9·461524
785	616225	483736025	28·0178515	9·224791	848	719104	609800192	29·1204396	9·465247
786	617796	485587656	28·0356915	9·228706	849	720801	611960049	29·1376046	9·468966
787	619369	487443403	28·0535203	9·232618	850	722500	614125000	29·1547595	9·472682
788	620944	489303872	28·0713377	9·237527	851	724201	616295051	29·1719043	9·476395
789	622521	491169069	28·0891438	9·240433	852	725904	618470208	29·1890390	9·480106
790	624100	493039000	28·1069386	9·244335	853	727609	620650477	29·2061637	9·483813
791	625681	494913671	28·1247222	9·248234	854	729316	622835864	29·2232784	9·487518
792	627264	496793088	28·1424946	9·252130	855	731025	625026375	29·2403830	9·491219
793	628849	498677257	28·1602557	9·256022	856	732736	627222016	29·2574777	9·494918
794	630436	500566184	28·1780056	9·259911	857	734449	629422793	29·2745623	9·498614
795	632025	502459875	28·1957444	9·263797	858	736164	631628712	29·2916370	9·502307
796	633616	504358336	28·2134720	9·267679	859	737881	633839779	29·3087018	9·505998
797	635209	506261573	28·2311884	9·271559	860	739600	636056000	29·3257566	9·509685
798	636804	508169592	28·2488938	9·275435	861	741321	638277381	29·3428015	9·513369
799	638401	510082399	28·2665881	9·279308	862	743044	640503928	29·3598365	9·517051
800	640000	512000000	28·2842712	9·283177	863	744769	642735647	29·3768616	9·520730
801	641601	513922401	28·3019434	9·287044	864	746496	644972544	29·3938769	9·524406
802	643204	515849608	28·3196045	9·290907	865	748225	647214625	29·4108823	9·528079
803	644809	517781627	28·3372546	9·294767	866	749956	649461896	29·4278779	9·531749
804	646416	519718464	28·3548938	9·298623	867	751689	651714363	29·4448637	9·535417
805	648025	521660125	28·3725219	9·302477	868	753424	653972032	29·4618397	9·539081
806	649636	523606616	28·3901391	9·306327	869	755161	656234909	29·4788059	9·542743
807	651249	525557943	28·4077454	9·310175	870	756900	658503000	29·4957624	9·546402
808	652864	527514112	28·4253408	9·314019	871	758641	660776311	29·5127091	9·550058
809	654481	529475129	28·4429253	9·317859	872	760384	663054848	29·5296461	9·553712
810	656100	531441000	28·4604989	9·321697	873	762129	665338617	29·5465734	9·557363
811	657721	533411731	28·4780617	9·325532	874	763876	667627624	29·5634910	9·561010
812	659344	535387328	28·4956137	9·329363	875	765625	669921875	29·5803989	9·564655
813	660969	537367797	28·5131549	9·333191	876	767376	672221376	29·5972972	9·568297
814	662596	539353144	28·5306852	9·337016	877	769129	674526133	29·6141858	9·571937
815	664225	541343375	28·5482048	9·340838	878	770884	676836152	29·6310648	9·575574
816	665856	543338496	28·5657137	9·344657	879	772641	679151439	29·6479325	9·579208
817	667489	545338513	28·5832119	9·348473	880	774400	681472000	29·6647939	9·582839
818	669124	547343432	28·6006993	9·352285	881	776161	683797841	29·6816442	9·586468
819	670761	549353259	28·6181760	9·356095	882	777924	686128968	29·6984848	9·590093

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
883	779689	688465387	29·7153159	9·593716	942	887364	835896888	30·6920185	9·802803
884	781456	690807104	29·7321375	9·597337	943	889249	838561807	30·7083051	9·806271
885	783225	693154125	29·7489496	9·600954	944	891136	841232384	30·7245830	9·809736
886	784996	695506456	29·7657521	9·604569	945	893025	843908625	30·7408523	9·813198
887	786769	697864103	29·7825452	9·608181	946	894916	846590536	30·7571130	9·816659
888	788544	700227072	29·7993289	9·611791	947	896809	849278123	30·7733651	9·820117
889	790321	702595369	29·8161030	9·615397	948	898704	851971392	30·7896086	9·823572
890	792100	704969000	29·8328678	9·619001	949	900601	854670349	30·8058436	9·827025
891	793881	707347971	29·8496231	9·622603	950	902500	857375000	30·8220700	9·830475
892	795664	709732288	29·8663690	9·626201	951	904401	860085351	30·8382879	9·833923
893	797449	712121957	29·8831056	9·629797	952	906304	862801408	30·8544972	9·837369
894	799236	714516984	29·8998328	9·633390	953	908209	865523177	30·8706981	9·840812
895	801025	716917375	29·9165506	9·636981	954	910116	868250664	30·8868904	9·844253
896	802816	719323136	29·9332591	9·640569	955	912025	870983875	30·9030743	9·847692
897	804609	721734273	29·9499583	9·644154	956	913936	873722816	30·9192497	9·851128
898	806404	724150792	29·9666481	9·647736	957	915849	876467493	30·9354166	9·854561
899	808201	726572699	29·9833287	9·651316	958	917764	879217912	30·9515751	9·857992
900	810000	729000000	30·0	9·654893	959	919684	881974079	30·9677251	9·861421
901	811801	731432701	30·0166620	9·658468	960	921600	884736000	30·9838668	9·864848
902	813604	733870808	30 0333148	9·662040	961	923521	887503681	31·0	9·868272
903	815409	736314327	30·0499584	9·665609	962	925444	890277128	31·0161248	9·871694
904	817216	738763264	30·0665928	9·669176	963	927369	893056347	31·0322413	9·875113
905	819025	741217625	30·0832179	9·672740	964	929296	895841344	31·0483494	9·878530
906	820836	743677416	30·0998339	9·676301	965	931225	898632125	31·0644491	9·881945
907	822649	746142643	30·1164407	9·679860	966	933156	901428696	31·0805405	9·885357
908	824464	748613312	30·1330383	9·683416	967	935089	904231063	31·0966236	9·888767
909	826281	751089429	30·1496269	9·686970	968	937024	907039232	31·1126984	9·892174
910	828100	753571000	30·1662063	9·690521	969	938961	909853209	31·1287648	9·895580
911	829921	756058031	30·1827765	9·694069	970	940900	912673000	31·1448230	9·898983
912	831744	758550528	30·1993377	9·697615	971	942841	915498611	31·1608729	9·902383
913	833569	761048497	30·2158899	9·701158	972	944784	918330048	31·1769145	9·905781
914	835396	763551944	30·2324329	9·704698	973	946729	921167317	31·1929479	9·909177
915	837225	766060875	30·2489669	9·708236	974	948676	924010424	31·2089731	9·912571
916	839056	768575296	30·2654919	9·711772	975	950625	926859375	31·2249900	9·915962
917	840889	771095213	30·2820079	9·715305	976	952576	929714176	31·2409987	9·919351
918	842724	773620632	30·2985148	9·718835	977	954529	932574833	31·2569992	9·922738
919	844561	776151559	30·3150128	9·722363	978	956484	935441352	31·2729915	9·926122
920	846400	778688000	30·3315018	9·725888	979	958441	938313739	31·2889757	9·929504
921	848241	781229961	30·3479818	9·729410	980	960400	941192001	31·3049517	9·932883
922	850084	783777448	30·3644529	9·732930	981	962361	944076141	31·3209195	9·936261
923	851929	786330467	30·3809151	9·736448	982	964324	946966168	31·3368792	9·939636
924	853776	788889024	30·3973683	9·739963	983	966289	949862087	31·3528308	9·943009
925	855625	791453125	30·4138127	9·743475	984	968256	952763904	31·3687743	9·940379
926	857476	794022776	30·4302481	9·746985	985	970225	955671625	31·3847097	9·949747
927	859329	796597983	30·4466747	9·750493	986	972196	958585256	31·4006369	9·953113
928	861184	799178752	30·4630924	9·753998	987	974169	961504803	31·4165561	9·956477
929	863041	801765089	30·4795013	9·757500	988	976144	964430272	31·4324673	9·959839
930	864900	804357000	30·4959014	9·761000	989	978121	967361669	31·4483704	9·963198
931	866761	806954491	30·5122926	9·764497	990	980100	970299000	31·4642654	9·966554
932	868624	809557568	30·5286750	9·767992	991	982081	973242271	31·4801525	9·969909
933	870489	812166237	30·5450487	9·771484	992	984064	976191488	31·4960315	9·973262
934	872356	814780504	30·5614136	9·774974	993	986049	979146657	31·5119025	9·976612
935	874225	817400375	30·5777697	9·778461	994	988036	982107784	31·5277655	9·979959
936	876096	820025856	30·5941171	9·782946	995	990025	985074875	31·5436206	9·983304
937	877969	822656953	30·6104557	9·785428	996	992016	988047936	31·5594677	9·986648
938	879844	825293672	30·6267857	9·788908	997	994009	991026973	31·5753068	9·989990
939	881721	827936019	30·6431069	9·792386	998	996004	994011992	31·5911380	9·993328
940	883600	830584000	30·6594194	9·795861	999	998001	997002999	31·6069613	9·996665
941	885481	833237621	30·6757233	9·799333	1000	1000000	1000000000	31·6227767	10·0

Sect. II.

GEOMETRY.

874. Geometry is that science which treats of the relations and properties of the boundaries of either body or space. The invention of the science has been referred to a very remote period: by some, to the Babylonians and Chaldeans; by others, to the Egyptians, who are said to have used it for determining the boundaries of their several lands, after the inundations of the Nile. Cassiodorus says that the Egyptians either derived the art from the Babylonians, or invented it after it was known to them. It is supposed that Thales, who died 548 B. C., and Pythagoras of Samos, who flourished about 520 B. C., introduced it from Egypt into Greece. We do not, however, consider it useful here to enter into the history of the science; neither is it necessary to enter into the reasons which have induced us to adopt the system of Rossignol, from whom we extract this section, otherwise than to state that we hope to conduct the student by a simpler and more intelligible method to those results with which he must be acquainted.

The limits of body or space are surfaces, and the boundaries of surfaces are lines, and the terminations of lines are points. Bounded spaces are usually called solids, whether occupied by body or not; the subject, therefore, is naturally divided into three parts, — lines, surfaces, and solids; and these have two varieties, dependent on their being straight or curved.

875. Geometrical inquiry is conducted in the form of propositions, problems, and demonstrations, being always the result of comparing equal parts or measures. Now, the parts compared may be either lines or angles, or both; hence, the nature of each method should be separately considered, and then the united power of both employed to facilitate the demonstration of propositions. But the reader must first understand the following

DEFINITIONS.

1. A solid is that which has length, breadth, and thickness. A slab of marble, for instance, is a solid, since it is long, broad, and thick.
2. A surface is that which has length and breadth, without thickness. A leaf of paper, though not in strictness, inasmuch as it has thickness, may convey the idea of a surface.
3. A line is that which has length, but neither breadth nor thickness. As in the case of a surface, it is difficult to convey the strict notion of a line, yet an infinitely thin line, as a hair, may convey the idea of a line: a thread drawn tight, a straight line.
4. A point is that which has neither length, breadth, nor thickness. A very fine grain of sand may give an idea of it.
5. If a line be carried about a point A, so that its other extremity passes from B to C, from C to D, &c. (*fig.* 223.), the point B, in its revolution, will describe a curve BCDFGLB. This curve line is called the *circumference* of a circle. The *circle* is the space enclosed by this circumference. The point A, which, in the formation of the circle is at rest, is called the *centre*. The right lines AC, AD, AF, &c. drawn from the centre to the circumference, are called *radii*. A *diameter* is a right line which passes through the centre, and is terminated both ways by the circumference. The line DAL, for example, is a diameter. An *arc* is a part of a circumference, as FG.

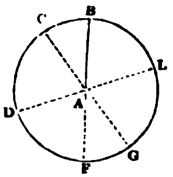


Fig. 223.

6. The circumference of a circle is divided into 360 equal parts, called *degrees*; each degree is divided into 60 parts, called *minutes*, and each minute into 60 parts, called *seconds*. Every circle, without relation to its magnitude, is supposed to be equally divided into degrees, minutes, and seconds.
7. Two right lines drawn from the same point, and diverging from each other, form an opening which is called an *angle*. An angle is commonly expressed by three letters, and it is usual to place in the middle that letter which marks the point whence the lines diverge; thus, we say the angle BAC or DAF (*fig.* 224.), and not the angle ABC or ACB.
8. The magnitude of an angle does not depend on the lines by which it is formed, but upon their distance from each other. How far soever the lines AB, AC are continued, the angle remains the same. One angle is greater than another when the lines of equal length by which it is formed are more distant. Thus the angle BAL (*fig.* 223.) is greater than the angle CAB, because the lines AB, AL are more distant from each other or include a greater arc than the lines AC, AB. If the legs of a pair of compasses be a little separated, an angle is formed; if they be opened wider, the angle becomes greater; if they be brought nearer, the angle becomes less.

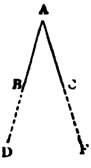


Fig. 224.

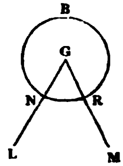


Fig. 225.

9. If the point of a pair of compasses be applied to the point G (*fig.* 225.), and a circumference NRB be described, the arc NR contained within the two lines GL, GM will measure the magnitude of the angle LGM. If the arc NR, for example, be an arc of 40 degrees, the angle LGM is an angle of 40 degrees.

10. There are three kinds of angles (*fig.* 226.): a *right* angle (I), which is an angle of 90 degrees; an *obtuse* angle (II), which contains more than 90 degrees; and an *acute* angle (III), which contains less than 90 degrees.

11. One line is *perpendicular* to another when the two angles it makes with that other line are equal: thus, the line CD (*fig.* 227.) is perpendicular to the line AB, if the angles CDA, CDB contain an equal number of degrees.

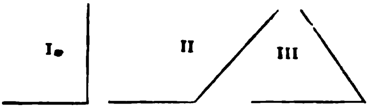


Fig. 226.

12. Two lines are *parallel* when all perpendiculars drawn from one to the other are equal; thus, the lines FG, AB (*fig.* 228.) are parallel, if all the perpendiculars *cd*, *cd*, &c. are equal.

13. A *triangle* is a surface enclosed by three right lines, called *sides* (*fig.* 229.). An *equilateral* triangle (I) is that which has three sides equal; an *isosceles* triangle has only two of its sides equal (II); a *scalene* triangle (III) has its three sides unequal.

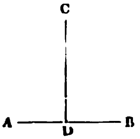


Fig. 227.

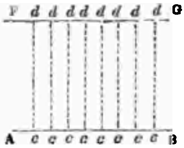


Fig. 228.

14. A *quadrilateral* figure is a surface enclosed by four right lines, which are called its sides.

15. A *parallelogram* is a quadrilateral figure, which has its opposite sides parallel; thus, if the side BC (*fig.* 230.) is parallel to the side AD, and the side AB to the side DC, the quadrilateral figure ABCD is called a parallelogram.

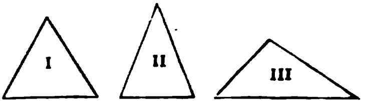


Fig. 229.

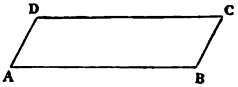


Fig. 230.

16. A *rectangle* is a quadrilateral figure all the angles whereof are right angles, as ABCD (*fig.* 231.).

17. A *square* is a quadrilateral figure whose sides are all equal and its angles right angles (*fig.* 232.).

18. A *trapezium* is any quadrilateral figure not a parallelogram.

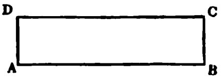


Fig. 231.

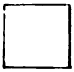


Fig. 232.

19. Those figures are *equal* which enclose an equal space; thus, a circle and a triangle are equal, if the space included within the circumference of the circle be equal to that contained in the triangle.

20. Those figures are *identical* which are equal in all their parts; that is, which have all their angles equal and their sides equal, and enclose equal spaces, as BAC, EDG (*fig.* 233.). It is manifest that two figures are identical which, being placed one upon the other, perfectly coincide, for in that case they must be equal in all their parts. It must be observed, that a line merely so expressed always denotes a right line.

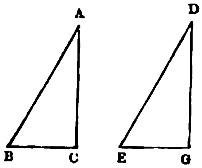


Fig. 233.

Axiom. Two right lines cannot enclose a space; that category requires at least three lines.

RIGHT LINES AND RECTILINEAL FIGURES.

876. Proposition I. *The radii of the same circle are all equal.*

The revolution of the line AB about the point A (*fig.* 234.) being necessary (Defin. 5.) to form the circle BCDFGLB, when in revolving the point B is upon the point C, the whole line AB must be upon the line AC; otherwise two right lines would enclose a space, which is impossible: wherefore the radius AC is equal to the radius AB. In like manner it may be proved that the radii AB, AF, AG, &c. are all equal to AB, and are therefore equal among themselves.

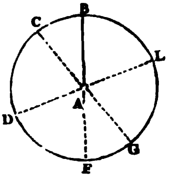


Fig. 234.

877. Prop. II. *On a given line to describe an equilateral triangle.*

Let AB (*fig.* 235.) be the given line upon which it is required to describe a triangle whose three sides shall be equal.

From the point A, with the radius AB, describe the circumference BCD, and from the point B, with the radius BA, describe the circumference ACF; and from the point C, where these two circumferences cut each other, draw the two right lines CA, CB. Then ACB is an equilateral triangle.

For the line AC is equal to the line AB, because these two lines are radii of the same circle BCD; and the line BC is equal to the line AB, because these two lines (Prop. 1.) are radii of the same circle ACF. Wherefore the lines AC and BC, being each equal to the line AB, are equal to one another, and all the three sides of the triangle ACB are equal; that is, the triangle is equilateral.

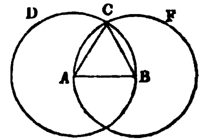


Fig. 235

878. Prop. III. *Triangles which have two sides and the angle subtended or contained by them equal are identical.*

In the two triangles BAC, FDG (*fig.* 236.), if the side DF be equal to the side AB, and the side DG equal to the side AC, and also the angle at D equal to the angle at A, the two triangles are identical.

Suppose the triangle FDG placed upon the triangle BAC in such manner that the side DF fall exactly upon the side equal to it, AB. Since the angle D is equal to the angle A, the side DG must fall upon the side equal to it, AC; also the point F will be found upon the point B, and the point G upon the point C: consequently the line FG must fall wholly upon the line BC, otherwise two right lines would enclose a space, which is impossible. Wherefore the three sides of the triangle FDG coincide in all points with the three sides of the triangle BAC, and the two triangles have their sides and angles equal, and enclose an equal space; that is (Defin. 20.), they are identical.

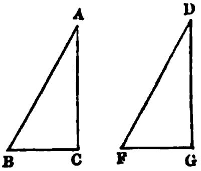


Fig. 236.

879. Prop. IV. *In an isosceles triangle the angles at the base are equal.*

Let the triangle BAC (*fig.* 237.) have its sides AB, AC equal, the angles B and C at the base are also equal. Conceive the angle A to be bisected by the right line AD.

In the triangles BAD, DAC the sides AB, AC are, by supposition, equal; the side AD is common to the two triangles, and the angles at A are supposed equal. These two triangles, therefore, have two sides, and the angle contained by them equal. Hence, they are identical (Prop. 3), or have all ther parts equal: whence the angles B and C must be equal.

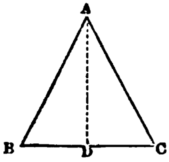


Fig. 237.

880. Prop. V. *Triangles which have their three sides equal are identical.*

In the two triangles ACB, FDG (*fig.* 238.), let the side AC be equal to the side FD, the side CB equal to the side DG, and the side AB to the side FG; these two triangles are identical.

Let the two triangles be so joined that the side FG shall coincide with the side AB (*fig.* 239.), and draw the right line CD. Since in the triangle CAD the side AC is equal to the side AD, the triangle is isoceles; whence (Defin. 13.) the angles *m* and *n* at the base are equal.

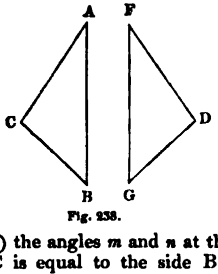


Fig. 238.

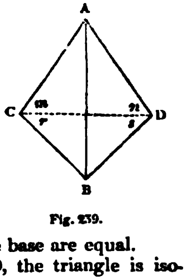


Fig. 239.

Since in the triangle CBD the side BC is equal to the side BD, the triangle is isosceles; whence (Defin. 13.) the angles *r* and *s* at the base are equal.

Because the angle *m* is equal to the angle *n*, and the angle *r* equal to the angle *s*, the whole angle C is equal to the whole angle D.

Lastly, because in the two triangles ACB, ADB the side AC is equal to the side AD and the side CB equal to the side DB, also the angle C equal to the angle D, these two triangles have two sides, and the contained angle equal, and are therefore (Prop. 3.) identical.

881. Prop. VI. *To divide a right line into two equal parts.*

Let the right line which it is required to divide into two equal parts be AB (*fig.* 240.). Upon AB draw (Prop. 2.) the equilateral triangle ADB, and on the other side of the same line

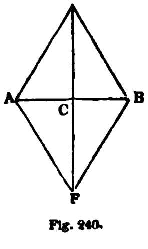


Fig. 240.

AB draw the equilateral triangle AFB, draw also the right line DF; AC is equal to CB.

In the two larger triangles DAF, DBF the sides DA, DB are equal, because they are the sides of an equilateral triangle; the sides AF, BF are equal for the same reason; and the side DF is common to the two triangles. These two triangles, then, have their sides equal, and consequently (Prop. 5.) are identical, or have all their parts equal; wherefore the two angles at D are equal.

Again, in the two smaller triangles ADC, CDB the side DA is made equal to the side DB, and the side DC is common to the two triangles; also the two angles at D are equal. Thus these two triangles have two sides and the contained angle equal; they are therefore (Prop. 3.) identical, and AC is equal to CB; that is, AB is bisected.

882. **Prop.** VII. *From a given point out of a right line to draw a perpendicular to that line.*

Let C (*fig.* 241.) be the point from which it is required to draw a perpendicular to the right line AB.

From the point C describe an arc of a circle which shall cut the line AB in two points F and G. Then bisect the line FG, and to D, the point of division, draw the line CD: this line is perpendicular to the line AB. Draw the lines CF, CG.

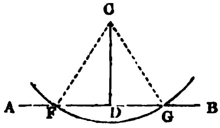


Fig. 241.

In the triangles FCD, DCG the sides CF, CG are equal, because (Prop. 1.) they are radii of the same circle; the sides FD DG are equal, because FG is bisected; and the side CD is common. These two triangles, then, having the three sides equal, are identical (Prop. 5.). Whence (Defin. 20.) the angle CDA is equal to the angle CDB, and consequently (Defin. 11.) the line CD is perpendicular to the line AB.

883. **Prop.** VIII. *From a given point in a right line to raise a perpendicular upon that line.*

From the point C (*fig.* 242.), let it be required to raise a perpendicular upon the right line AB.

In AB take at pleasure CF equal to CG; upon the line FG describe an equilateral triangle FDG, and draw the line CD; this line will be perpendicular to AB.

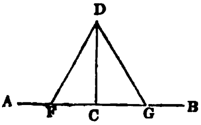


Fig. 242.

In the triangles FDC, CDG the sides DF, DG are equal, because they are the sides of an equilateral triangle; the sides FC, CG are equal by construction; and the side DC is common. These two triangles, then, having the three sides equal, are (Prop. 5.) identical. Therefore (Defin. 20.) the angle DCA is equal to the angle DCB, and consequently (Defin. 11.) the line CD is perpendicular to the line AB.

884. **Prop.** IX. *The diameter of a circle divides the circumference into two equal parts.*

Let ADBLA (*fig.* 243.) be a circle; the diameter ACB bisects the circumference, that is, the arc ALB is equal to the arc ADB.

Conceive the circle to be divided, and the lower segment ACBLA to be placed upon the upper ACBDA; all the points of the arc ALB will fall exactly upon the arc ADB; and consequently these two arcs will be equal.

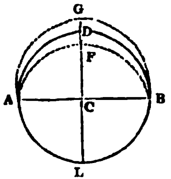


Fig. 243.

For if the point L, for instance, does not fall upon the arc ADB, it must fall either above this arc, as at G, or below it, as at F. If it fall on G, the radius CL will be greater than the radius CD; if it falls on F, the radius CL will be less than the radius CD, which is (Prop. 1.) impossible. The point L, then, must fall upon the arc ADB. In like manner it may be proved that all the other points of the arc ALB must fall upon the arc ADB: those two arcs are therefore equal.

885. **Prop.** X. *A right line which meets another right line forms with it two angles, which, together, are equal to two right angles.*

The line AC (*fig.*244.) meeting the line DF, and forming with it the two angles ACD, ACF, these two angles are together equal to two right angles.

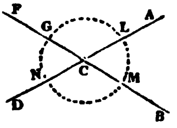


Fig. 244.

From the point C as a centre describe at pleasure a circumference NGLMN.

The line NCL, being a diameter, divides the circumference (Prop. 9.) into two equal parts. The arc NGL is therefore half the circumference, which contains (Defin. 6.) 180, or twice 90 degrees. Therefore the angles ACD, ACF, which, taken together, are measured by the arc NGL, are twice 90 degrees, that is (Defin. 10.), are equal to two right angles.

886. **Prop.** XI. *A line drawn perpendicularly to another right line makes right angles with it.*

If the line CD (*fig.* 245.) be perpendicular to the line AB, the angle CDA is a right angle, and also the angle CDB.

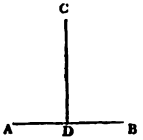


Fig. 245.

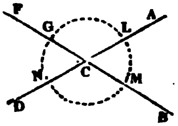


Fig. 246.

For the line CD, meeting the line AB, forms with it two angles, which are together (Prop. 10.) equal to two right angles; and these two angles are equal, because CD is perpendicular to AB. Wherefore each angle is a right angle.

887. Prop. XII. *If two lines cut each other, the vertical or opposite angles are equal.*

Let the lines AB, DF (*fig.* 246.) cut each other at the point C; the angles ACD, FCB, which are called vertical or opposite angles, are equal.

From the point C, as a centre, describe at pleasure a circumference NGLMN.

Since the line NCL is a diameter, the arc NGL is (Prop. 9.) half the circumference; therefore the arcs NGL, GLM are equal. From these two arcs take away the common part GL, there will remain the arc NG equal to the arc LM. Consequently the angles ACD, FCB, which are measured by these two arcs, are also equal.

888. Prop. XIII. *If a line be perpendicular to one of two parallel lines, it is also perpendicular to the other.*

Let AB, CD (*fig.* 247.) be two parallel lines: if the line FG makes right angles with CD, it will also make right angles with AB.

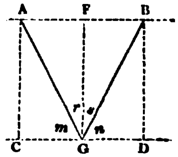


Fig. 247.

Take at pleasure GC equal to GD; at the points C and D raise the perpendiculars CA, DB, and draw the lines GA, GB.

In the two triangles ACG, BDG, because the line AB is parallel to the line CD, the perpendiculars CA, DB are necessarily equal, as appears from the definition of parallel lines (Defin. 12.); the lines CG, DG are equal by construction; and the angles C and D are right angles. The two triangles ACG, BDG have then two sides and the contained angle equal, they are therefore (Prop. 3.) identical. Whence the side GA is equal to the side GB, and the angle *m* equal to the angle *n*.

Again, in the triangles AGF, FGB the side GA is equal to the side GB, as has been proved, and the side GF is common. Moreover, the angle *r* is equal to the angle *s*; for if from the two right angles FGC, FGD be taken away the equal angles *m* and *n*, there will remain the equal angles *r* and *s*. The triangles AGF, FGB have then two sides and the contained angle equal; they are therefore (Prop. 3.) identical. Wherefore the angles GFA, GFB are equal, and consequently are right angles.

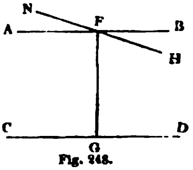


Fig. 248.

889. Prop. XIV. *If one line be perpendicular to two other lines, these two lines are parallel.*

Let the line FG (*fig.* 248.) make right angles with the lines AB and CD; these two lines are parallel.

If the line AB be not parallel to the line CD, another line, as NH, may be drawn through the point F, parallel to the line CD. But this is impossible; for if the line NH were parallel to the line CD, the line FG making right angles with CD would also (Prop. 13.) make right angles with NH; which cannot be, because, by supposition, it makes right angles with AB.

890. Prop. XV. *The opposite sides of a rectangle are parallel.*

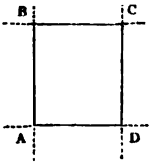


Fig. 249.

In the rectangle ABCD (*fig.* 249.) the side BC is parallel to the side AD, and the side AB parallel to the side DC. Produce each of the sides both ways.

The line AB is perpendicular to the two lines BC, AD; the two lines BC, AD are therefore (Prop. 14.) parallel. In like manner, the line AD is perpendicular to the two lines AB, DC; the two lines AB, DC are therefore (Prop. 14.) parallel.

891. Prop. XVI. *The opposite sides of a rectangle are equal.*

In the rectangle ABCD (see *fig.* 249.) the side AB is equal to the side DC, and the side BC equal to the side AD. For, since the side BC is parallel to the side AD, the perpendiculars AB, DC are (Defin. 12.) equal; and since the side AB is parallel to the side DC, the perpendiculars BC, AD are equal.

892. Prop. XVII. *A right line falling upon parallel lines makes the alternate angles equal.*

Let the line FG (*fig.* 250.) cut the parallels AB, GD; the angles AFG, FGD, which are called *alternate angles*, are equal. From the point G draw GL perpendicular to the line AB, and from the point F draw FM perpendicular to the line GD.

Since the line GL is perpendicular to AB, it is also (Prop. 13.) perpendicular to the parallel line AB. Whence the quadrilateral figure GLFM is a rectangle, its four angles being right angles.

In the triangles GLF, FMG the sides LF, GM are equal, because they are opposite sides of the same rectangle; the sides LG, FM are equal for the same reason; and the side FG is common. The two triangles GLF, FMG have then the three sides equal, and consequently (Prop. 5.) are identical. Wherefore the angle LFG opposite to the side LG is equal to the angle FGM opposite to the side FM.

Remark. In identical triangles the equal angles are always opposite to equal sides, as by this proposition appears.

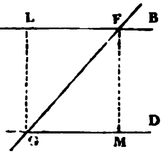


Fig. 250.

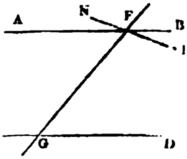


Fig. 251.

893. PROP. XVIII. *If one right line falling upon two others makes the alternate angles equal, these two lines are parallel.*

Let the alternate angles AFG, FGD (*fig.* 251.) be equal; the lines AB, GD are parallel.

If the line AB is not parallel to the line GD, another line, as NH, may be drawn through the point F parallel to GD. But this is impossible; for if the line NH were parallel to the line GD, the angle FGD would be (Prop. 17.) equal to the angles NFG, since these two angles would be alternate angles between two parallel lines; which cannot be, because, by supposition, the angle FGD is equal to the angle AFG.

894. PROP. XIX. *If one right line falls upon two parallel right lines, it makes the interior angle equal to the exterior.*

Let the line FG (*fig.* 252.) meet the parallel lines BA, DC, the interior angle *r* is equal to the exterior angle *z*. Produce the lines BA, DC.

The angle *r* (Prop. 17.) is equal to the angle *s*, because these are alternate angles, made by a right line falling upon two parallel lines, and the angles *s* and *z* are (Prop. 12.) equal, because they are vertical or opposite angles; therefore the angle *r* is equal to the angle *z*.

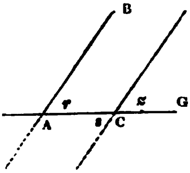


Fig. 252.

895. PROP. XX. *If one right line falling upon two other right lines makes the internal angle equal to the external, those two lines are parallel.*

Let the internal angle *r* (*fig.* 253.) be equal to the external angle *z*, the lines BA, DC are parallel.

The angle *r* is equal to the angle *z* by supposition, and the angle *z* (Prop. 12.) is equal to the angle *s*, because they are opposite angles. The alternate angles *r*, *s* are therefore equal, and consequently (Prop. 18.) the lines BA, DC are parallel.

896. PROP. XXI. *Through a given point to draw a line parallel to a given line.*

Let G be the point through which it is required to draw a line parallel to the given line MF.

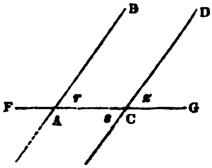


Fig. 253.

From any point G (*fig.* 254.) describe, at pleasure, the arc FN; from the point F, in which the arc FN cuts the line MF, with the distance GF describe the arc GM meeting the line MF in M; then make FL equal to GM, and draw the line GL; this line is parallel to the line MF.

Draw the line GF.

The arcs GM, FL are equal by construction; therefore the alternate angles *r*, *s*, which are measured by these arcs (Defin. 9.), are equal; and consequently (Prop. 18.) the lines GL, MF are parallel.

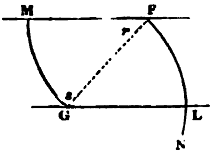


Fig. 254.

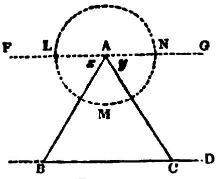


Fig. 255.

897. PROP. XXII. *The three angles of a triangle taken together are equal to two right angles.*

In the triangle BAC (*fig.* 255.), the three angles B, A, C are together equal to two right angles.

Produce the side BC both ways; through the point A draw a line FG parallel to BC; and from the point A, as a centre, describe any circumference LMN.

The angle B (Prop. 17.) is equal to the angle *x*, because these are alternate angles made by a right line falling upon two parallel lines. For the same reason the angle C is equal to the angle *y*.

Because LAN is a diameter, the arc LMN is half the circumference; therefore the three angles *x*, A, *y*, which are measured by this arc, are together equal to two right angles.

But the angle x is equal to the alternate angle B, and the angle y to the alternate angle C.

Therefore, substituting B for x, and C for y, the three angles B, A, C are together equal to two right angles.

Corollary. Hence, if two angles of any triangle be known, the third is also found; since the third angle is that which the other two taken together wants of two right angles.

898. Prop. XXIII. *If two triangles have two angles equal, they have also the third angle equal.*

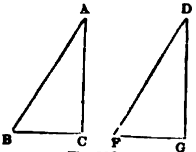


Fig. 256.

In the two triangles BAC, FDG (*fig.* 256.), if the angle B is equal to the angle F, and the angle A equal to the angle D, the angle C will also be equal to the angle G.

Since the angle C (Corol. to Prop. 22.) is that which the angles B and A together want of two right angles; and since the angle G is that which F and D together want of two right angles; the angles B and A being equal to the angles F and D, the angle C must be equal to the angle G.

899. Prop. XXIV. *The exterior angle of any triangle is equal to the two interior and opposite angles taken together.*

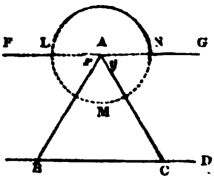


Fig. 257.

In the triangle BAC (*fig.* 257.) produce one of the sides BC; the angle ACD, which is called *exterior*, is equal to the two *interior* and *opposite* angles B and A taken together.

The line AC meeting the line BD forms with it two angles, which are together (Prop. 10.) equal to two right angles; the angle ACB is therefore that which the angle ACD wants of two right angles. But the angle ACB is (Corol. to Prop. 22.) also that which the angles B and A together want of two right angles. Wherefore the angle ACD is equal to the two angles B and A taken together.

900. Prop. XXV. *Triangles which have two angles and the side which lies between them equal are identical.*

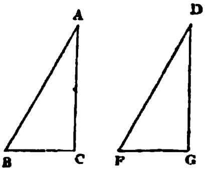


Fig. 258.

In the two triangles BAC, FDG (*fig.* 258.), if the angle F is equal to the angle B, the angle G equal to the angle C, and the side FG equal to the side BC, these two triangles are identical.

Conceive the triangle FDG placed upon the triangle BAC in such a manner that the side FG shall fall exactly upon the equal side BC. Since the angle F is equal to the angle B, the side FD must fall upon the side BA; and since the angle G is equal to the angle C, the side GD must fall upon the side CA. Thus the three sides of the triangle FDG will be exactly placed upon the three sides of the triangle BAC; and consequently the two triangles (Prop. 5.) are identical.

901. Prop. XXVI. *If two angles of a triangle are equal, the sides opposite to those angles are also equal.*

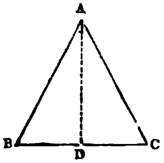


Fig. 259.

Conceive the angle A (*fig.* 259.) to be bisected by the line AD.

In the triangles BAD, DAC the angle B is equal to the angle C by supposition, and the angles at A are also equal. These two triangles have their two angles equal; the third angle will therefore (Prop. 23.) be equal; whence the angles at D are equal. Moreover, the side AD is common to the two triangles. These two triangles, therefore, having two angles and the side which lies between them equal, are (Prop. 25.) identical. Wherefore the side AB is equal to the side AC.

902. Prop. XXVII. *The opposite sides of a parallelogram are equal.*

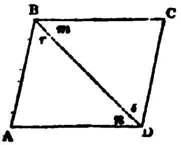


Fig. 260.

In the parallelogram ABCD (*fig.* 260.), the side AB is equal to the side DC, and the side BC equal to the side AD.

Draw the line BD, which is called the *diagonal.*

Because BC is parallel to AD, the alternate angles m and n are equal. In like manner, because AB is parallel to DC, the alternate angles r and s are equal. Also, the side BD is common to the two triangles BAD, BCD. These two triangles have then two angles and the side which lies between them equal, and are therefore (Prop. 3.) identical. Wherefore the side AB opposite to the angle n is (Prop. 26.) equal to the side DC opposite to the angle m; and the side BC opposite to the angle s is equal to the side AD opposite to the equal angle r.

Corollary. Hence, the diagonal bisects the parallelogram; for the triangles BAD, BCD, having the three sides equal, are identical.

903. Prop. XXVIII. *Parallelograms which are between the same parallels, and have the same base, are equal.*

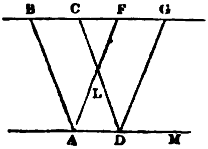


Fig. 261.

Let the two parallelograms ABCD, AFGD (*fig.* 261.), be between the same parallels BG, AM, and upon the same base AD; the space enclosed within the parallelogram ABCD is equal to the space enclosed within the parallelogram AFGD.

In the two triangles BAF, CDG the side BA of the former triangle is equal to the side CD of the latter, because they are opposite sides of the same parallelogram. For the same reason, the side FA is equal to the side GD. Moreover, BC is equal to AD, because they are opposite sides of the same parallelogram. For the same reason, AD is equal to FG. BC is therefore equal to FG. If to both these CF be added, BF will be equal to CG. Whence the two triangles BAF, CDG, having the three sides equal, are (Prop. 5.) identical, and consequently have equal surfaces.

If from these two equal surfaces be taken the small triangle CLF, which is common, there will remain the trapezium ABCL, equal to the trapezium LFGD. To these two trapezia add the triangle ALD, and the parallelogram ABCD will be equal to the parallelogram AFGD.

904. Prop. XXIX. *If a triangle and a parallelogram are upon the same base, and between the same parallels, the triangle is equal to half the parallelogram.*

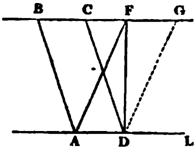


Fig. 262.

Let the parallelogram ABCD (*fig.* 262.) and the triangle AFD be upon the same base AD, and between the same parallels BG, AL; the triangle AFD is half the parallelogram ABCD. Draw DG parallel to AF.

Because the parallelogram AFGD is bisected by the diagonal FD (Prop. 27. Corol.), the triangle AFD is half the parallelogram AFGD. But the parallelogram AFGD is equal to the parallelogram ABCD, because these two parallelograms are upon the same base, and between the same parallels; therefore the triangle AFD is equal to half the parallelogram ABCD.

905. Prop. XXX. *Parallelograms which are between the same parallels, and have equal bases, are equal.*

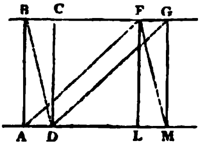


Fig. 263.

Let the two parallelograms ABCD, LFGM (*fig.* 263.) be between the same parallels BG, AM, and have the equal bases AD, LM; these two parallelograms are equal.

Draw the lines AF, DG.

Because AD is equal to LM, and LM to FG, AD is equal to FG; and they are parallel by construction. Also AF and DG are parallel; for if DG be not parallel to AF, another line may be drawn parallel to it; whence FG will become greater or less than AD. AF and AG are therefore parallel, and AFGD a parallelogram.

Now the parallelogram ABCD is (Prop. 28.) equal to the parallelogram AFGD, because these two parallelograms are between the same parallels, and have the same base AD. And the parallelogram AFGD is equal to the parallelogram LFGM, because these two parallelograms are between the same parallels, and have the same base FG. The parallelogram ABCD is therefore equal to the parallelogram LFGM.

906. Prop. XXXI. *Triangles which are between the same parallels, and have equal bases, are equal.*

Let the two triangles ABD, LFM (see *fig.* to preceding Proposition) be between the same parallels BG, AM, and upon the equal bases AD, LM; these two triangles are equal.

Draw DC parallel to AB, and MG parallel to LF.

The two parallelograms ABCD, LFGM are equal (Prop. 30.), because they are between the same parallels, and have equal bases. But the triangle ABD is (Prop. 29.) one half of the parallelogram ABCD, and the triangle LFM is one half of the parallelogram LFGM; these two triangles are therefore equal.

907. Prop. XXXII. *In a right-angled triangle, the square of the hypothenuse, or side subtending the right angle, is equal to the squares of the sides which contain the right angle.*

In the triangle BAC (*fig.* 264.), let the angle A be a right angle. Upon the hypothenuse BC describe the square BDFC; upon the side AB describe the square ALMB, and upon the side AC the square ARNC; the square BDFC is equal to the two squares ALMB, ARNC taken together.

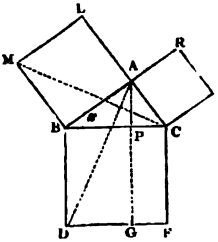


Fig. 264.

Draw the right lines MC, AD, and draw AG parallel to BD.

Because the square or parallelogram MLAB and the triangle MCB are between the same parallels LC, MB, and have the same base MB, the triangle MCB is (Prop. 29.) equal to half the square ALMB.

Again, because the rectangle or parallelogram DGPB and the triangle DAB are between the same parallels GA and DB, and have the same base DB, the triangle DAB is (Prop. 29.) equal to half the rectangle DGBP.

Further, since the side MB of the triangle MBC and the side AB of the triangle ABD are sides of the same square, they are (Defin. 17.) equal. Also, since the side BC of the first triangle and the side BD of the second triangle are sides of the same square, they are equal. And because the angle MBC of the first triangle is composed of a right angle and the angle x, and the angle ABD of the second triangle is composed of a right angle and the same angle x, therefore these two angles, contained between the equal sides MB, BC and AB, BD, are equal. Wherefore the two triangles MBC, ABD, having two sides and the contained angle equal, are (Prop. 3.) identical, and consequently equal.

But the triangle MBC is half the square MLAB, and the triangle ABD is half the rectangle BDGP; the square and the rectangle are therefore equal.

In the same manner it may be demonstrated that the square ARNC and the rectangle CFGP are equal. Wherefore it follows that the whole square BDFC is equal to the two squares MLAB, ARNC taken together.

CIRCLES.

908. Definitions. — 1. A right line (*fig.* Prop. 33. AB) terminated both ways by the circumference of a circle is called a *chord.*

2. A line (*fig.* Prop. 39. AB) which meets the circumference in one point only is called a *tangent;* and the point T is called the *point of contact.*

3. An angle (*fig.* Prop. 33. ABD) which has its vertex in the circumference of a circle is called *an angle in the circle.*

4. A part of a circle confined between two radii (*fig.* Prop. 34. ACBFA) is called a *sector.*

5. A part of a circle (*fig.* Prop. 35. AGBDA) terminated by a chord is called a *segment of a circle.*

909. Prop. XXXIII. *To draw the circumference of a circle through three given points.*

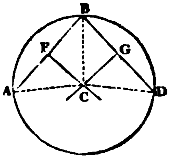


Fig. 265.

Let there be three given points, A, B, D (*fig.* 265.), through which it is required to draw the circumference of a circle. Draw the right lines AB, BD, and bisect them: from the points of the division F, G, raise the perpendiculars BC, GC; and at the point C with the radius CA describe the circumference of a circle; this circumference will pass through the points B and D. Draw the lines CA, CB, CD.

In the triangles CFA, CFB the side FA is equal to the side FB by construction, the side FC is common, and the two angles at F are right angles. These two triangles, then, have two sides and the angle contained by them equal; they are therefore (Prop. 3.) identical. Consequently the side CB is equal to the side CA.

For the same reason, the triangles CGB, CGD are also identical. Wherefore the side CD is equal to the side CB, and consequently equal to CA.

And since the right lines CB, CD are equal to the right line CA, it is manifest (Prop. 1.) that the circumference which passes through the point A must also pass through the point D.

910. Prop. XXXIV. *If a radius bisect a chord, it is perpendicular to that chord.*

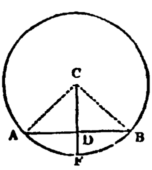


Fig. 266.

If the radius CF (*fig.* 266.) bisect the chord AB, the angles CDA, CDB are right angles. Draw the radii CA, CB.

In the triangles CDA, CDB the sides CA, CB, being radii, are equal (Prop. 1.), the sides AD, DB are equal by supposition, and the side CD is common. These two triangles, having the three sides equal, are therefore (Prop. 5.) identical. Wherefore the angles CDA, CDB are equal, and consequently (Prop. 10.) are right angles.

Corollary. The two angles at C are also (Prop. 5.) equal.

Hence it appears, that any angle ACB may be bisected by describing from its vertex C as the centre with any radius AC an arc AFB; bisecting the chord of that arc AB; and then drawing from the point of division D the right line CD; for it may then be shown, as in the proposition, that the triangles ACD, DCB are identical, and consequently the angles at C equal.

911. Prop. XXXV. *To find the centre of a circle.*

Let the circle of which it is required to find the centre be AGBF. Draw any chord AB (*fig.* 267.); bisect it, and from the point of division D raise a perpendicular FG: this line will pass through the centre, and consequently, if it be bisected, the point of division will be the centre.

If the centre of the circle be not in the line FG, it must be somewhere out of it; for instance, at the point L. But this is impossible, for if the point L were the centre, the right line LM would be a radius; and since this line bisects the chord AB, it is (Prop. 34.) perpendicular to AB; which cannot be, since CD is perpendicular to AB.

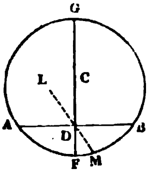


Fig. 267.

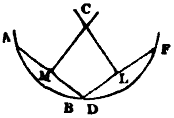


Fig. 268.

912. Prop. XXXVI. *To find the centre of an arc of a circle.*

Let ABDF be the arc of which it is required to find the centre. Draw any two chords AB, DF (*fig.* 268); bisect them, and from the points of division raise the perpendiculars MC, LC; the point C, in which these two perpendiculars cut each other, is the centre of the arc.

For (Prop. 35.) the perpendicular MC and the perpendicular LC both pass through the centre of the same circle; this centre must therefore be the point C, which is the only point common to the two perpendiculars.

913. Prop. XXXVII. *If three equal lines meet in the same point within a circle, and are terminated, they are radii of that circle.*

The lines CA, CB, CD (*fig.* 269.), drawn from the same point C within a circle, and terminated by it, being equal, the point C is the centre of the circle. Draw the lines AB, BD; bisect them, and let the points of division be F, G; and draw the lines CF, CG.

In the triangles CFA, CFB, the sides CA, CB are equal by supposition, the sides FA, FB are equal by construction, and the side CF is common. These two triangles, then, have the three sides equal; they are therefore (Prop. 5.) identical. Wherefore the two angles at F are equal, and the line FC (Defin. 11.) is perpendicular to the chord AB. And since this perpendicular bisects the chord AB, it must (Prop. 35.) pass through the centre of the circle. In like manner, it may be demonstrated that the line GC also passes through the centre. Wherefore the point C is the centre of the circle, and CA, CB, CD are radii.

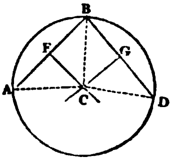


Fig. 269.

914. Prop. XXXVIII. *If the radius of a circle be perpendicular to a chord, the radius bisects both the chord and the arc of the chord.*

Let the radius CF be perpendicular to the chord AB (*fig.* 270.); the right line AD is equal to the right line DB, and the arc AF equal to the arc FB. Draw the right lines CA, CB.

In the large triangle ACB, the side CA (Prop. 1.) is equal to the side CB, because they are radii of the same circle. The angle A is (Prop. 4.) therefore equal to the angle B. The angles at D are right angles, and therefore equal; and the angles at C are consequently (Prop. 23.) equal. Also the side CA is equal to the side CB, and the side CD is common. These two triangles, then, having two sides and the angle contained by them equal, are (Prop. 3.) identical, whence the side AD is equal to the side DB. Again, since the angles ACF, BCF are equal, the arcs AB, BF, which measure these angles, are also equal. The chord AB and the arc AFB are therefore bisected by the radius CF.

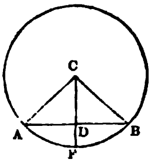


Fig. 270.

915. Prop. XXXIX. *A right line perpendicular to the extremity of a radius is a tangent to the circle.*

Let the line AB (*fig.* 271.) pass through the extremity of the radius CT in such a manner that the angles CTA, CTB shall be right angles; this line AB touches the circumference in only one point T. If AB touch the circumference in any other point, let it be D, and draw the line CD.

In the right-angled triangle CTD the square of the hypothenuse CD is equal to the two squares of CT and TD taken together. The square of CD is therefore greater than the square of CT, and consequently the line CD is greater than the line CT, which is a radius. Therefore the point D is out of the circumference. And in like manner it may be shown that every point in the line AB is out of the circumference, except T; AB is therefore a tangent to the circle.

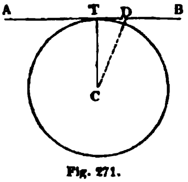


Fig. 271.

Corollary. It follows, therefore, that a perpendicular is the shortest line that can be drawn from any point to a given line; since the perpendicular CT is shorter than any other line which can be drawn from the point C to the line AB.

916. Prop. XL. *If a right line be drawn touching a circumference, a radius drawn to the point of contact will be perpendicular to the tangent.*

Let the line AB (*fig.* 272.) touch the circumference of a circle in a point T, the radius CT is perpendicular to the tangent AB. For all other lines drawn from the point C to the line AB must pass out of the circle to arrive at this line. The line CT is therefore the shortest which can be drawn from the point C to the line AB, and consequently (Corol. to Prop. 39.) is perpendicular to the line AB.

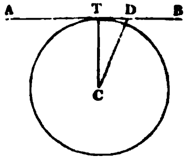


Fig. 272.

917. Prop. XLI. *The angle formed by a tangent and chord is measured by half the arc of that chord.*

Let BTA (*fig.* 273.) be a tangent and TD a chord drawn from the point of contact T; the angle ATD is measured by half the arc TFD, and the angle BTD is measured by half the arc TGD. Draw the radius CT to the point of contact, and the radius CF perpendicular to the chord TD.

The radius CF being perpendicular to the chord TD (Prop. 38.) bisects the arc TFD. TF is therefore half the arc TFD.

In the triangle CML the angle M being a right angle, the two remaining angles are (Prop. 22.) equal to a right angle. Wherefore the angle C is that which the angle L wants of a right angle. On the other side, since the radius CT is perpendicular to the tangent BA, the angle ATD is also that which the angle L wants of a right angle. The angle ATD is therefore equal to the angle C. But the angle C is measured by the arc TF, consequently the angle ATD is also measured by the arc TF, which is half of TFD. The angle BTD must therefore be measured by half the arc TGD, since these two halves of arcs make up half the circumference.

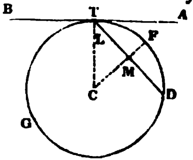


Fig. 273.

918. Prop. XLII. *An angle at the circumference of a circle is measured by half the arc by which it is subtended.*

Let CTD (*fig.* 274.) be the angle at the circumference; it has for its measure half the arc CFD by which it is subtended.

Suppose a tangent passing through the point T.

The three angles at T are measured by half the circumference (Prop. 22.), but the angle ATD is measured (Prop. 41.) by half the arc TD, and the angle BTC by half the arc TC; consequently the angle CTD must be measured by half the arc CFD, since these three halves of arcs make up half the circumference.

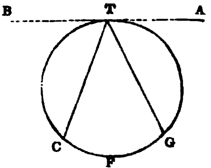


Fig. 274.

919. Prop. XLIII. *The angle at the centre of a circle is double of the angle at the circumference.*

Let the angle at the circumference ADB (*fig.* 275.) and the angle at the centre ACB be both subtended by the same arc AB, the angle ACB is double of the angle ADB.

For the angle ACB is measured by the arc AB, and the angle ADB is (Prop. 42.) measured by half the same arc AB; the angle ACB is therefore double of the angle ADB.

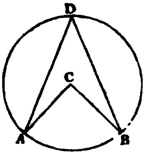


Fig. 275.

920. Prop. XLIV. *Upon a given line, to describe a segment of a circle containing a given angle.*

Let AB (*fig.* 276.) be the given line and G the given angle, it is required to draw such a circumference of a circle through the points A and B that the angle D shall be equal to the angle G.

For this purpose draw the lines AL, BL in such manner that the angles A and B shall be equal to the angle G; at the extremities of LA, LB raise the perpendiculars AB, BC; and from the point C in which these two perpendiculars cut each other, with the radius CA or CB describe the circumference ADB; the angle D will be equal to the angle G.

The angle LAB, formed by the tangent AL and the chord AB, is (Prop. 41.) measured by half the arc AFB; and the angle D at the circumference is also measured (Prop. 42.) by half the arc AFB; the angle D is therefore equal to the angle LAB. But the angle LAB is made equal to the angle G; the angle D is therefore equal to the angle G.

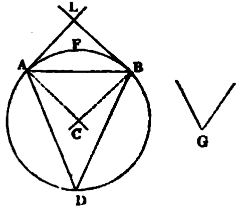


Fig. 276.

921. Prop. XLV. *In every triangle the greater side is opposite to the greater angle, and the greater angle to the greater side.*

In the triangle ABC (*fig.* 277.), if the side AB be greater than the side AC, the angle

C opposite to the side AB will be greater than the angle B opposite to the side AC. Draw the circumference of a circle through the three points A, C, B.

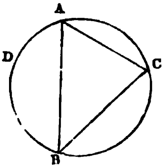


Fig. 277.

Since the chord AB is greater than the chord AC, it is manifest that the arc ADB is greater than the arc AFC; and consequently the angle at the circumference C, which is measured (Prop. 42.) by half the arc ADB, is greater than the angle at the circumference B, which is measured by half the arc AFC.

Again, if the angle C is greater than the angle B, the side AB opposite to the angle C will be greater than the side AC opposite to the angle B.

The angle C is measured (Prop. 42.) by half the arc ADB, and the angle B by half the arc AFC. But the angle C is greater than the angle B; the arc ADB is therefore greater than the arc AFC, and consequently the chord AB is greater than the chord AC.

922. PROP. XLVI. *Two parallel chords intercept equal arcs.*

If the two chords AB, CD (*fig.* 278.) are parallel, the arcs AC, BD are equal. Draw the right line BC.

Because the lines AB, CD are parallel, the alternate angles ABC, BCD are (Prop. 17.) equal. But the angle at the circumference BCD is measured (Prop. 42.) by half the arc AC; and the angle at the circumference BCD is measured by half the arc BD; the arcs AC, BD are therefore equal.

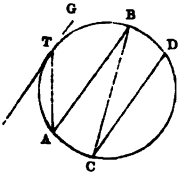


Fig. 278.

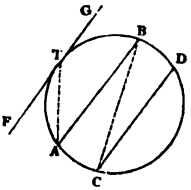


Fig. 279.

923. PROP. XLVII. *If a tangent and chord be parallel to each other, they intercept equal arcs.*

Let the tangent FG (*fig.* 279.) be parallel to the chord AB; the arc TA will be equal to the arc TB. Draw the right line TA.

Because the lines FG, AB are parallel, the alternate angles FTA, TAB are (Prop. 17.) equal. But the angle FTA, formed by a tangent and a chord, is measured (Prop. 41.) by half the arc TA, and the angle at the circumference TAB is measured (Prop. 42.) by half the arc TB. The halves of the arcs TA, TB, and consequently the arcs themselves, are therefore equal.

924. PROP. XLVIII. *The angle formed by the intersection of two chords is measured by half the two arcs intercepted by the two chords.*

Let the two chords AB, DF (*fig.* 280.) cut each other at the point C, the angle FCB or ACD is measured by half the two arcs FB, AD. Draw AG parallel to DF.

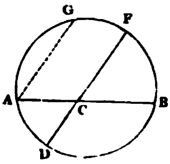


Fig. 280.

Because the lines AG, DF are parallel, the interior and exterior angles GAB, FCB are (Prop. 19.) equal. But the angle at the circumference GAB is measured (Prop. 42.) by half the arc GFB. The angle FCB is therefore also measured by half the arc GFB.

Because the chords AG, DF are parallel, the arcs GF, AD are (Prop. 46.) equal: AD may therefore be substituted in the room of GF; wherefore the angle FCB is measured by half the arcs AD, FB.

925. PROP. XLIX. *The angle formed by two secants is measured by half the difference of the two intercepted arcs.*

Let the angle CAB (*fig.* 281.) be formed by the two secants AC, AB, this angle is measured by half the difference of the two arcs GD, CB, intercepted by the two secants. Draw DF parallel to AC.

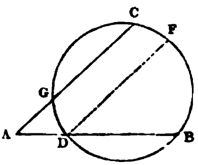


Fig. 281.

Because the lines AC, DF are parallel, the interior and exterior angles CAB, FDB are (Prop. 19.) equal. But the angle FDB is measured (Prop. 42.) by half the arc FB; the angle GAB is therefore also measured by half the arc FB.

Because the chords GC, DF are parallel, the arcs GD, CF are (Prop. 46.) equal; the arc FB is therefore the difference of the arc GD and the arc CFB. Where the angle A has for its measure half the difference of the arcs GD, CFB.

926. PROP. L. *The angle formed by two tangents is measured by half the difference of the two intercepted arcs.*

Let the angle CAB (*fig.* 282.) be formed by the two tangents AC, AB; this angle is measured by half the difference of the two arcs GLD, GFD. Draw DF parallel to AC.

Because the lines AC, DF are parallel, the interior and exterior angles CAB, FDB are (Prop. 19.) equal. But the angle FDB, formed by the tangent DB and the chord DF, is measured (Prop. 41.) by half the arc FD. Therefore the angle CAB is also measured by half the arc FD.

Because the tangent AC and the chord DF are parallel, the intercepted arcs GF GD are (Prop. 47.) equal. The arc FD is therefore the difference between the arc GLD and the arc GFD. Therefore the angle CAB, which is measured by half the arc FD, is also measured by half the difference of the arcs GLD, GFD.

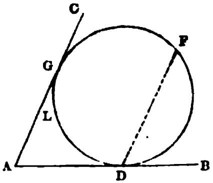


Fig. 282.

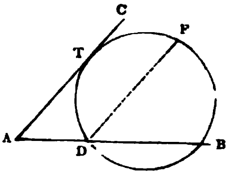


Fig. 283.

Corollary. In the same way it may be demonstrated that the angle formed by a tangent ATC (*fig.* 283.) and a secant ADB is measured by half the difference of the two intercepted arcs.

927. Prop. LI. *To raise a perpendicular at the extremity of a given line.*

At the extremity A (*fig.* 284.) of the given line AB let it be required to raise a perpendicular.

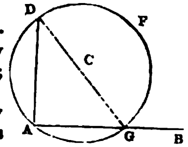


Fig. 284.

From any point C taken above the line AB describe a circumference passing through the point A and cutting the line AB in any other point, as G. Draw the diameter DG and the right line AD; this line AD will be perpendicular to the line AB.

The angle DAG at the circumference is measured (Prop. 42.) by half the arc DFG, which is half the circumference, because DCG is a diameter. The angle DAG is therefore measured by one fourth part of the circumference, and consequently (Defin. 10.) is a right angle, whence the line AD is (Prop. 11.) perpendicular to the line AB.

Corollary. Hence it follows that the angle at the circumference which is subtended by a diameter must be a right angle.

928. Prop. LII. *From any point without a circle to draw a tangent to that circle.*

From the point A (*fig.* 285.) let it be required to draw a tangent to the circle DTB.

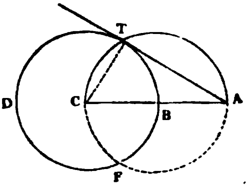


Fig. 285.

Draw from the centre C any right line CA; bisect this right line, and from the point of division B, as a centre, describe the arc CTA. Lastly, from the point A, and through the point T, in which the two arcs cut each other, draw the right line AT; this right line AT will be a tangent to the circle DTB. Draw the radius CT.

The angle CTA at the circumference, being subtended by the diameter CA, is (Corol. to Prop. 51.) a right angle; therefore the line TA is perpendicular to the extremity of the radius CT, and consequently (Prop. 40.) is a tangent to the circle DTB.

SURFACES.

929. Definitions.—1. A *mathematical point* has neither length, breadth, nor thickness. The *physical point*, now for consideration, has a supposed length and breadth exceedingly small.

2. A *physical line* is a series of physical points, and consequently its breadth is equal to that of the physical points whereof it is composed.

3. Since physical lines are composed of points, as numbers are composed of units, points may be called the *units* of lines.

4. As to multiply one number by another is to take or repeat the first number as many times as there are units in the second; so to *multiply one line by another* is to take or repeat the first line as many times as there are units, that is, physical points, in the second.

930. Prop. LIII. *The surface of a rectangle is equal to the product of its two sides.*

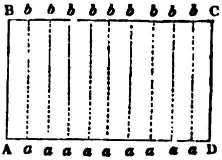


Fig. 286.

Let the rectangle be ABCD (*fig.* 286.). If the physical line AB be multiplied by the physical line AD, the product will be the surface ABCD.

If as many physical lines equal to AB as there are physical points in the line AD be raised perpendicularly upon AD, these lines AB, *ab*, &c. will fill up the whole surface of the rectangle ABCD. Wherefore the surface ABCD is equal to the line AB taken as many times as there are physical points in the line AD; that is, (Defin. 4.) equal to the line AB multiplied by the line AD.

931. Prop. LIV. *The surface of a triangle is equal to half the product of its altitude and base.*

If from the vertex of any angle A (*fig.* 287.) of the triangle BAC be drawn AD, perpendicular to the opposite side BC, this perpendicular is called the *height*, and the side BC the *base* of the triangle. Now the surface of the triangle is equal to half the product of the height AD and the base BC.

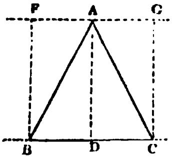


Fig. 287.

Produce BC both ways; through the point A draw FG parallel to BC, and raise the two perpendiculars BF, CG.

Because the rectangle BFGC and the triangle BAC are between the same parallels, and have the same bases, the triangle is (Prop. 29.) half the rectangle. But the surface of the rectangle is equal (Prop. 53.) to the product of BF and BC. Wherefore the surface of the triangle is equal to half the product of BF and BC, that is, of DA and CC.

932. Prop. LV. *To measure the surface of any rectilineal figure.*

Let ABCDFA (*fig.* 288.) be the rectilineal figure, whereof it is required to find the surface.

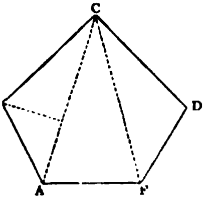


Fig. 288.

Divide the whole figure into triangles by drawing the lines CA, CF. Then, drawing a perpendicular from the point B to the side CA, multiply these two lines; the half of their product will (Prop. 54.) give the surface of the triangle ABC. In the same manner let the surfaces of the remaining triangles ACF, FCD be found. These three surfaces added together will give the whole surface of the figure ABCDFA.

933. Prop. LVI. *The area of a circle is equal to half the product of its radius and circumference.*

If the radius of the circle C (*fig.* 289.) be multiplied by its circumference, the half of the product will give the surface of the circle.

Two physical points being manifestly not sufficient to make a curve line, this must require at least three. If, therefore, all the physical points of a circumference be taken two by two, these will compose a great number of small right lines. From the extremities L, M of one of these small right lines if two radii LC MC be drawn, a small triangle LCM will be formed, the surface of which will be equal to half the product of its height; that is, the radius and its base.

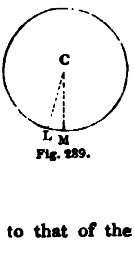


Fig. 289.

To find the surface of all the small triangles whereof the circle is composed, multiply the height, that is, the radius, by all the bases, that is, by the circumference, and take the half of the product; whence the area or surface of the circle will be equal to half the product of the radius and circumference.

934. Prop. LVII. *To draw a triangle equal to a given circle.*

Let it be required to form a triangle the surface of which shall be equal to that of the circle AGFDA (*fig.* 290.).

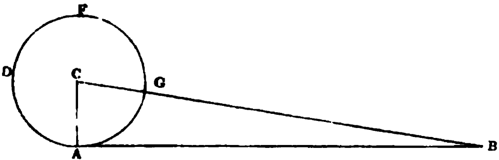


Fig. 290.

At the extremity of any radius CA of the circle, raise a perpendicular AB equal to the circumference AGFD, and draw the right line CB. The surface of the triangle BCA will be equal to that of the circle AGFDA.

The surface of the circle is equal (Prop. 56.) to half the product of the radius CA and the circumference, or the line AB. The surface of the triangle is also equal (Prop. 54.) to half the product of its height CA, or radius, and its base BA, or circumference. Therefore the surface of the triangle is equal to that of the circle.

PROPORTION.

935. Definitions. — 1. The ratio of one quantity to another is the number of times which the first contains the second; thus the ratio of 12 to 3 is four, because 12 contains 3 four times; or, more universally, *ratio* is the comparative magnitude of one quantity with respect to another.

2. Four quantities are *proportional*, or *in geometrical proportion*, or two quantities are said to have the same ratio with two others, when the first contains or is contained in the second, exactly the same number of times which the third contains or is contained in the fourth; thus, the four numbers 6, 3, 8, 4 are proportionals, because 6 contains 3 as many times as 8 contains 4, and 3 is contained in 6 as many times as 4 is contained in 8, that is, twice; which is thus expressed: 6 is to 3 as 8 to 4; or 3 is to 6 as 4 to 8.

936. Prop. LVIII. *Parallelograms which are between the same parallels are to one another as their bases.*

Let the two parallelograms ABCD, FGLM (*fig.* 291.) be between the same parallels BL, AM, the surface of the parallelogram ABCD contains the surface of the parallelogram FGLM as many times exactly as the base AD contains the base FM. Suppose, for example, that the base AD is triple of the base FM; in this case the surface ABCD will also be triple of the surface FGLM.

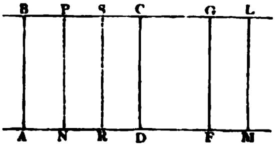


Fig. 291.

Divide the base AD into three parts, each of which is equal to the base FM, and draw from the points of division the lines NP, RS parallel to the side AB.

The parallelograms ABPN, FGLM being between the same parallels and having equal bases, the parallelogram ABPN is (Prop. 30.) equal to the parallelogram FGLM. For the same reason, the parallelograms NPSR, RSCD are also equal to the parallelogram FGLM. The parallelogram ABCD is therefore composed of three parallelograms, each of which is equal to the parallelogram FGLM. Consequently the parallelogram ABCD is triple of the parallelogram FGLM.

937. Prop. LIX. *Triangles which are between the same parallels are to one another as their bases.*

Let the two triangles ABC, DFG (*fig.* 292.) be between the same parallels LF, AG, the surface of the triangle ABC contains the surface of the triangle DFG as many times as the base AC contains the base DG. Suppose, for example, that the base AC is triple of the base DG, in this case the surface ABC will be triple of the surface DFG.

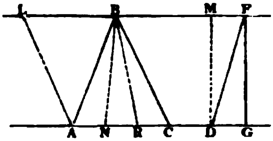


Fig. 292.

Divide the base AC into three equal parts, AN, NR, RC, each of which is equal to the base DG, and draw the right lines BN, BR.

The triangles ABN, DFG being between the same parallels and having equal bases, the triangle ABN is (Prop. 31.) equal to the triangle DFG. For the same reason, the triangles NBR, RBC are each equal to the triangle DFG. The triangle ABC is therefore composed of three triangles, each of which is equal to the triangle DFG. Wherefore the triangle ABC is triple of the triangle DFG.

938. Prop. LX. *If a line be drawn in a triangle parallel to one of its sides, it will cut the other two sides proportionally.*

In the triangle BAC (*fig.* 293.), if the line DF be parallel to the side BC, it will cut the other two sides in such manner that the segment AD will be to the segment DB as the segment AF is to the segment FC. Suppose, for instance, the segment AD to be triple of the segment DB, the segment AF will be triple of the segment FC. Draw the diagonals DC, FB.

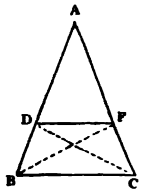


Fig. 293.

The triangles AFD, DFB are between the same parallels, as will be easily conceived by supposing a line drawn through the point F parallel to the side AB. These two triangles are therefore to one another (Prop. 59.) as their bases; and since the base AD is triple of the base DB, the triangle AFD will be triple of the triangle DFB.

Again, the triangles BFD, FDC are between the same parallels DF, BC, and upon the same base DF. These two triangles are therefore (Prop. 31.) equal; and since the triangle AFD is triple of the triangle DFB, it will also be triple of the triangle FDC.

Lastly, the triangles ADF, FDC are between the same parallels, as will be easily conceived by supposing a line drawn through the point D parallel to the side AC. These two triangles are therefore to one another (Prop. 59.) as their bases; and since the triangle ADF is triple of the triangle FDC, the base AF will be triple of the base FC.

939. Prop. LXI. *Equiangular triangles have their homologous sides proportional.*

In the two triangles ABC, CDF (*fig.* 294.), if the angle A be equal to the angle C, the angle B equal to the angle D, and the angle C equal to the angle F; the side AC, for example, opposite to the angle B is to the side CF opposite to the angle D as the side AB opposite to the angle C is to the side CD opposite to the angle F. Place the two triangles so that the sides AC, CF shall form one right line, and produce the sides AB, FD till they meet in G.

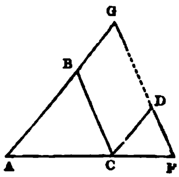


Fig. 294.

The interior and exterior angles GAF, DCF being equal, the lines GA, DC are (Prop. 20.) parallel. In like manner, the alternate angles GFA, BCA on the same sides being equal, the lines GF, BC are (Prop. 20.) parallel. Wherefore the quadrilateral figure BGDC is a parallelogram, and consequently its opposite sides are equal. In the triangle GAF the line BC, being parallel to the side

FG, cuts (Prop. 60.) the other two sides proportionally; that is, AC is to CP as AB is to BG, or its equal CD.

940. Prop. LXII. *Triangles the sides of which are proportional are equiangular.*

In the two triangles BAC, FDG (*fig.* 295.), if the side AB is to the side DF as the side BC is to the side FG and as the side AC to the side DG, these two triangles have their angles equal.

Let the side AB be supposed triple of the side DF; the side AC must be triple of the side DG, and the side BC triple of the side FG.

If the triangle FDG be not equiangular with the triangle BAC, another triangle may be formed equiangular with it; for example, FLG. But this is impossible; for if the two triangles BAC, FLG were equiangular, their sides would be (Prop. 61.) proportional; and BC being triple of FG, AB would be triple of LF. But AB is triple of DF; whence LF would be equal to DF. For the same reason, LG would be equal to DG. Thus, the two triangles FLG, FDG, having their three sides equal, would be (Prop. 5.) identical; which is absurd, since their angles are unequal.

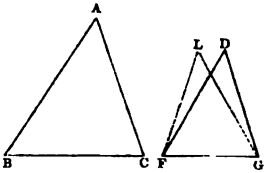


Fig. 295.

941. Prop. LXIII. *Triangles which have an angle in one equal to an angle in the other, and the sides about these angles proportional, are equiangular.*

If in the two triangles BAC, NMP (*fig.* 296.) the angle A be equal to the angle M, and the side AB be to the side MN as the side AC is to the side MP, the two triangles are equiangular.

If AB be triple of MN, AC must be triple of MP. Now, if the angle MNP, for example, is not equal to the angle ABC, another angle may be made, as MNR, which shall be equal to it. But this is impossible; for the two triangles BAC, NMR, having two angles equal, would be equiangular, and consequently (Prop. 61.) would have their sides proportional; wherefore, AB being triple of MN, AC would be triple of MR, which cannot be, since AC is triple of MP.

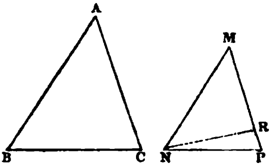


Fig. 296.

942. Prop. LXIV. *A right line which bisects any angle of a triangle divides the side opposite to the bisected angle into two segments, which are proportional to the two other sides.*

In the triangle BAC, let the angle BAC be bisected by the right line AD, making the angle *r* equal to the angle *s*. The segment BD is to the segment DC as the side BA to the side AC.

Produce the side BA, and draw CF parallel to DA.

The lines DA, CF being parallel, the interior and exterior angles *r*, F are (Prop. 19.) equal, and the alternate angles *s*, C are (Prop. 17.) also equal. And since the angle *r* is equal to the angle *s*, the angle F will also be equal to the angle C; and consequently the side AF is equal to the side AC.

In the triangle BFC, the line AD being parallel to the side FC; BD (Prop. 60.) will be to DC as BA is to AF, or its equal AC.

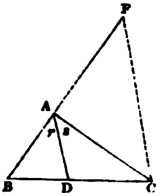


Fig. 297.

943. Prop. LXV. *To find a fourth proportional to three given lines.*

Let the three lines be A, B, C (*fig.* 298.), it is required to find a fourth line D, such that the line A shall be to the line B as the line C is to the line D.

Form any angle RFG, make FM equal to the line A, MG equal to the line B, and FN equal to the line C; draw the right line MN, and through the point G draw GL parallel to MN; NL will be the fourth proportional required.

In the triangle FLG the line NM, being parallel to the side LG, cuts the other two sides (Prop. 60.) proportionally. Wherefore FM is to MG as FN is to NL; that is, A is to B as C is to D.

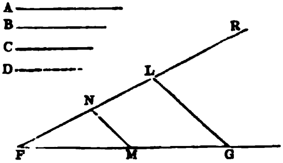


Fig. 298.

944. Prop. LXVI. *To find a third proportional to two given lines.*

Let the two lines be A, B (*fig.* 299.), it is required to find a third line C, such that the line A shall be to the line B as the line B is to the line C.

Form any angle LFG, make FM equal to the line A, MG equal to the line B, and FN equal to the line B; draw the right line MN, and through the point G draw GL parallel to MN; NL will be the third proportional required.

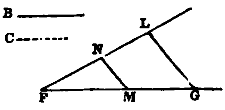


Fig. 299.

In the triangle FLG the line NM, being parallel to the side LG, cuts the other two sides (Prop. 60.) proportionally. Wherefore FM is to MG as FN is to NL; that is, A is to B as B is to C.

945. Prop. LXVII. *If four lines be proportional, the rectangle or product of the extremes is equal to the rectangle or product of the means.*

Let the line A be to the line B as the line C is to the line D (*fig.* 300.); the rectangle formed by the lines A and D is equal to the rectangles formed by the lines B and C.

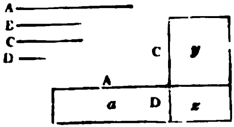


Fig. 300.

Let the four lines meet in a common point, forming at that point four right angles; and draw the lines parallel to them to complete the rectangles *x*, *y*, *z*.

If the line A be triple of the line B, the line C will be triple of the line D.

The rectangles or parallelograms *x*, *z* being between the same parallels, are to one another as their bases. Since the base A is triple of the base B, the rectangle *x* is triple of the rectangle *z*. In like manner, the rectangles or parallelograms *y*, *z*, being between the same parallels, are to one another as their bases: since the base C is triple of the base D, the rectangle *y* is therefore triple of the rectangle *z*. Wherefore, the rectangle *x* being triple of the rectangle *z*, and the rectangle *y* being triple of the same rectangle *z*, these two rectangles *x* and *y* are equal to one another.

946. Prop. LXVIII. *Four lines which have the rectangle or product of the extremes equal to the rectangle or product of the means are proportional.*

Let the four lines A, B, C, D (*fig.* 301.) be such that the rectangle of A and D is equal to the rectangle of B and C, the line A will be to the line B as the line C to the line D.

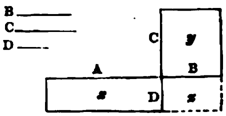


Fig. 301.

Let the four lines meet in a common point, forming at that point four right angles, and complete the rectangles *x*, *y*, *z*.

If the line A be triple of the line B, the line C will be triple of the line D.

The rectangles *x* and *z*, being between the same parallels, are to one another as their bases: since the base A is triple of the base B, the rectangle *x* will be therefore triple of the rectangle *z*. And the rectangle *y* is, by supposition, equal to the rectangle *x*; the rectangle *y* is therefore also triple of the rectangle *z*.

But the rectangles *y*, *z*, being between the same parallels, are to one another as their bases. Hence, since the rectangle *y* is triple of the rectangle *z*, the base C is also triple of the base D.

947. Prop. LXIX. *If four lines be proportional, they are also proportional alternately.*

If the line A is to the line B as the line C to the line D (*fig.* 302.), they will be in proportion *alternately*; that is, the line A will be to the line C as the line B to the line D.

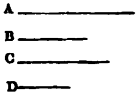


Fig. 302.

Because the line A is to the line B as the line C is to the line D, the rectangle of the extremes A and D is equal to the rectangle of the means B and C; whence it follows (Prop. 68.) that the line A is to the line C as the line B is to the line D.

Otherwise, — Suppose the line A to be triple of the line B, the line C will be triple of the line D. Hence, instead of saying A is to B as C to D, we may say three times B is to B as three times D is to D. Now it is manifest that three times B is to three times D as B is to D. Therefore the line A (which is equal to three times B) is to the line C (which is equal to three times D) as the line B is to the line D.

948. Prop. LXX. *If four lines be proportional, they will be proportional by composition.*

Let the line A be to the line B as the line C is to the line D (*fig.* 303.), they will be proportional by *composition*; that is, the line A joined to the line B will be to the line B as the line C joined to the line D is to the line D.

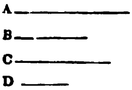


Fig. 303.

If the line A contain the line B, for example, three times, and the line C contain the line D three times; the line A joined to the line B will contain the line B four times, and the line C joined to the line D will contain the line D four times. Therefore the line A joined to the line B is to the line B as the line C joined to the line D is to the line D.

949. Prop. LXXI. *If four lines be proportional, they will be also proportional by division.*

If the line A is to the line B as the line C is to the line D (*fig.* 304.), they will be proportional by *division*; that is, the line A wanting the line B is to the line B as the line C wanting the line D is to the line D.

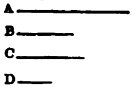


Fig. 304.

If the line A contain the line B, for example, three times, and the line C contain the line D three times, the line A wanting the line B will contain the line B only twice; and the line C wanting the line D will also contain the line D twice. Therefore the line A wanting the line B is to the line B as the line C wanting the line D is to the line D.

950. Prop. LXXII. *If three lines be proportional, the first is to the third as the square of the first is to the square of the second.*

If the line CD is to the line cd as the line cd is to a third line x (*fig.* 305.), the line CD is to the line x as the square of the line CD is to the square of the line cd. Take CF equal to the line x, and draw the perpendicular FB.

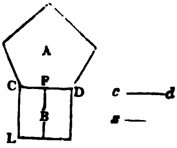


Fig. 305.

Since the line CD is to the line cd as the line cd is to the line CF, the rectangle of the extremes CF, CD, or CL is equal (Prop. 67.) to the rectangle of the means, that is, to the square of cd.

Again, the square of CD and the rectangle of the lines CF, CL, being between the same parallels, are to one another (Prop. 58.) as their bases. Therefore CD is to CF, or x, as the square of CD is to the rectangle of CF and CL, or to its equal the square of cd.

951. Prop. LXXIII. *If two chords in a circle cut each other, the rectangle of the segments of one is equal to the rectangle of the segments of the other*

Let the two chords AB, CD (*fig.* 306.) in the circle cut each other in the point F, the rectangle of AF, FB is equal to the rectangle of CF, FD. Draw the two right lines AC, DB. Because in the triangles CAF, BDF the angles at the circumference A and D are both measured (Prop. 42.) by half the arc CB, they are equal. Because the angles C and B are both measured (Prop. 42.) by half the arc AD, these angles are also equal. And the angles at F are equal, because they are vertical. These two triangles are therefore equiangular, and consequently (Prop. 61.) their sides are proportional. Wherefore the side AF opposite to the angle C is to the side FD opposite to the angle B as the side CF opposite to the angle A is to the side FB opposite to the angle D. Therefore (Prop. 69.) the rectangle of the extremes AF, FB is equal to the rectangle of the means CF, FD.

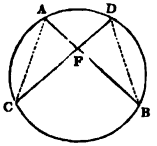


Fig. 306.

952. Prop. LXXIV. *To find a mean proportional between two given lines.*

Let there be two lines A, C (*fig.* 307.), it is required to find a third line B, such that the line A shall be to the line B as the line B is to the line C.

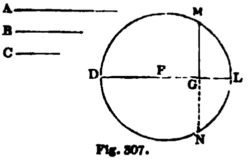


Fig. 307.

Place the lines A and C in such manner that they shall form one right line DGL, and bisect this right line in the point F. From the point F, as a centre, describe the circumference of a circle DMLN; then, at the point G, where the two lines are joined, raise the perpendicular GM; GM is the mean proportional sought between the lines A and C. Produce MG to N.

Because the chords DL, MN cut each other at the point G, the rectangle of the segments DG, GL is (Prop. 73.) equal to the rectangle of the segments MG, GN.

Because the radius FL is perpendicular to the chord MN, FL (Prop. 38.) bisects MN; therefore GN is equal to GM.

Lastly, because the rectangle of the extremes DG, GL is equal to the rectangle of the means GM, GN, or its equal GM, DG is to GM as GM is to GL. Therefore GM is a mean proportional between DG and GL, that is, between the lines A and C.

953. Prop. LXXV. *The bases and altitudes of equal triangles are in reciprocal or inverse ratio.*

Let the two triangles ABC, DFG (*fig.* 308.) be equal; the base AC will be to the base DG, as the perpendicular FM to the perpendicular BL; that is, the bases and altitudes are in *reciprocal* or *inverse* ratio.

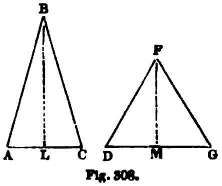


Fig. 308.

The triangle ABC (Prop. 54.) is half the product or rectangle of the base AC and the altitude BL. Again, the triangle DFG is (Prop. 54.) half the product or rectangle of the base DG and the altitude FM. The two triangles being equal, the two rectangles, which are double of the triangles, will therefore also be equal.

Again, because the rectangle of the extremes AC, BL is equal to the rectangle of the means DG, FM; AC (Prop. 68.) is to DG as FM is to BL.

954. Prop. LXXVI. *Triangles the bases and altitudes whereof are in reciprocal or inverse ratio are equal.*

In the two triangles ABC, DFG (*fig.* 309.), if the base AC be to the base DG as the perpendicular FM to the perpendicular BL, the surfaces of the two triangles are equal.

Because AC is to DG as FM is to BL, the product or rectangle of the extremes AC, BL is (Prop. 67.) equal to the product or rectangle of the means DG, FM. The halves (Corol. to Prop. 27.) of these two rectangles, namely, triangles ABC, DFG, are therefore equal.

955. Prop. LXXVII. *Two secants drawn from the same point to a circle are in the inverse ratio of the parts which lie out of the circle.*

Let the two secants be CA, CB (*fig.* 310.); CA is to CB as CD is to CF. Draw the right lines FB, DA.

In the triangles CDA, CFB the angles at the circumference A and B, being both measured (Prop. 42.) by half the arc FD, are equal, and the angle C is common to the two triangles. These two triangles are therefore (Prop. 23.) equiangular and (Prop. 61.) have their sides proportional. Wherefore the side CA of the first triangle is to the side CB of the second triangle as the side CD of the first triangle is to the side CF of the second triangle.

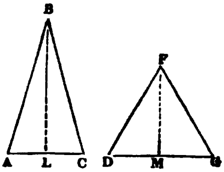


Fig. 309.

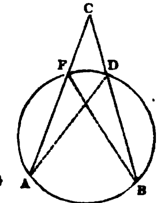


Fig. 310.

956. Prop. LXXVIII. *The tangent to a circle is a mean proportional between the secant and the part of the secant which lies out of the circle.*

In the circle ABD, CB (*fig.* 311.) being secant, and CA tangent, CB is to CA as CA is to CD. Draw the right lines AB, AD.

The triangles CAB, CDA have the angle C common to both. Also the angle B is measured (Prop. 42.) by half the arc AFD; and the angle CAD formed by the tangent AC and the chord AD is measured (Prop. 41.) by half the same arc AFD. The two triangles CAB, CDA, having their two angles equal, are (Prop. 23.), equiangular, and consequently (Prop. 61.) have their sides proportional. Hence the side CB of the greater triangle opposite to the angle CAB is to the side CA of the smaller triangle opposite to the angle D as the side CA of the greater triangle opposite to the angle B is to the side CD of the smaller triangle opposite to the angle A.

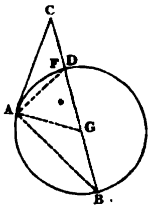


Fig. 311.

Corollary. From this proposition is suggested a new method of finding a mean proportional between two given lines.

Take CB equal to one of the given lines, and CD equal to the other; bisect DB; from the point of division, as a centre, describe the circumference DAB; and draw the tangent CA. This tangent is a mean proportional between CB and CD, as appears from the proposition.

957. Prop. LXXIX. *To cut a given line in extreme and mean ratio.*

Let it be required to divide the line CA (*fig.* 312.) in extreme and mean ratio; that is, to divide it in such a manner that the whole line shall be to the greater part as the greater part is to the less.

At the extremity A of the line CA raise a perpendicular AG equal to half the line CA; from the point G, as a centre, with the radius GA, describe the circumference ADB; draw the line CB through the centre, and take CF equal to CD; the line CA will be divided at the point F in extreme and mean ratio.

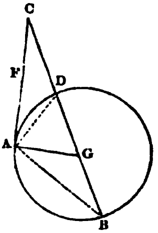


Fig. 312.

Because (Prop. 78.) CB is to CA as CA is to CD, by division, (Prop. 71.) CB wanting CA or its equal DB is to CA, as CA wanting CD or its equal CF is to CD; that is, CD or CF is to CA, as FA is to CD or CF; or, inversely, CA is to CF as CF is to FA, or the line AC is cut in extreme and mean ratio.

SIMILAR FIGURES.

958. Definitions. — 1. Figures are *similar* which are composed of an equal number of physical points disposed in the same manner. Thus, the figures ABCDF, *abcdf* (*fig.* 313.) are similar, if every point of the first figure has its corresponding point placed in the same manner in the second.

Hence it follows, that if the first figure is, for example, three times greater than the second, the points of which it is composed are three times greater than those of the second figure.

2. In similar figures, those lines are said to be *homologous* which are composed of an equal number of corresponding points.

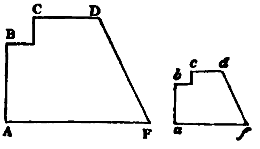


Fig. 313.

959. PROP. LXXX. *In similar figures the homologous sides are proportional.*

Let the similar figures be ABCDF, *abcdf* (*fig.* 314.), and the homologous lines CA, *ca*, CF, *cf*; CA is to CF as *ca* to *cf*.

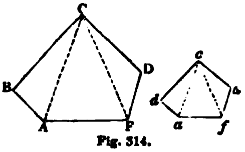


Fig. 314.

Since the lines CA, *ca* are homologous, they are composed of an equal number of corresponding points; as are also the homologous lines CF, *cf*. If, for instance, the line CA is composed of 40 equal points, and the line CF of 30, the line *ca* will necessarily be composed of 40 points, and the line *cf* of 30; and it is manifest that 40 is to 30 as 40 to 30. Therefore CA is to CF as *ca* to *cf*.

960. PROP. LXXXI. *The circumference of circles are as their radii.*

The circumference DCB (*fig.* 315.) is to the radius AB as the circumference *dcb* is to the radius *ab*.

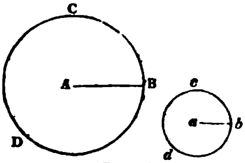


Fig. 315.

All circles are similar figures, that is, are composed of an equal number of points disposed in the same manner. They have therefore (Prop. 80.) their homologous lines proportional. Therefore the circumference DCB is to the radius AB as the circumference *dcb* is to the radius *ab*.

961. PROP. LXXXII. *Similar figures are to each other as the squares of their homologous sides.*

Let the two similar figures be A, *a* (*fig.* 316.) Upon the homologous sides CD, *cd* form the squares B, *b*. The surface A is to the surface *a* as the square B is to the square *b*.

Since the figures A, *a* are similar, they are composed of an equal number of corresponding points; and since the homologous sides CD, *cd* are composed of an equal number of points, the squares drawn upon these lines B, *b* are also composed of an equal number of points.

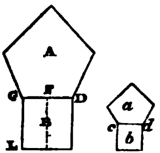


Fig. 316.

If it be supposed that the surface A is composed of 1000 points and the square B of 400 points, the surface A will be also composed of 1000 points and the square *b* of 400. Now it is manifest that 1000 is to 400 as 1000 to 400. Wherefore the surface A is to the square B as the surface *a* is to the square *b*; and, alternately (Prop. 69.), the surface A is to the surface *a* as the square B to the square *b*.

COROLLARY. It follows that if any three similar figures be formed upon the three sides of a right-angled triangle, the figure upon the hypothenuse will be equal to the other two taken together; for these three figures will be as the squares of their sides; therefore, since the square of the hypothenuse is equal to the two squares of the other sides, the figure formed upon the hypothenuse will also be equal to the two other similar figures formed upon the other sides.

962. PROP. LXXXIII. *Circles are to each other as the squares of their radii.*

Let two circles DCB, *dcb* (*fig.* 317.) be drawn.

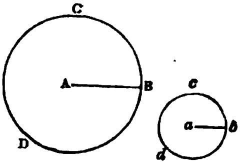


Fig. 317.

The surface contained within the circumference DCB is to the surface contained within the circumference *dcb* as the square formed upon the radius AB to the square formed upon the radius *ab*.

The two circles, being similar figures, are composed of an equal number of corresponding points, and the radii AB, *ab* being composed of an equal number of points, the squares of these radii will also be composed of an equal number of points. Suppose, for example, that the greater circle DCB is composed of 800 points, and the square of the greater radius AB of 300 points, the smaller circle *dcb* will also be composed of 800 points, and the square of the smaller radius of 300. Now it is manifest that 800 is to 300 as 800 to 300. Therefore the greater circle DCB is to the square of its radius AB as the smaller circle *dcb* is to the square of its radius *ab*; and, alternately, the greater circle is to the lesser circle as the greater square is to the lesser square.

963. PROP. LXXXIV. *Similar triangles are equiangular.*

If the two triangles ABC, *abc* (*fig.* 318.) be composed of an equal number of points disposed in the same manner, they are equiangular.

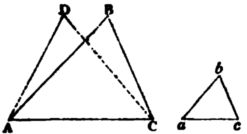


Fig. 318.

For, since the triangles ABC, *abc* are similar figures, they have their sides (Prop. 80.) proportional; they are therefore (Prop. 62.) equiangular.

964. PROP. LXXXV. *Equiangular triangles are similar.*

If the triangles ABC, *abc* are equiangular, they are also similar. See *fig.* 318.

If the triangle ABC were not similar to the triangle *abc*, another triangle might be formed upon the line AC; for example, ADC, which should be similar to the triangle *abc*. Now, the triangle ADC, being similar to the triangle *abc*, will also (Prop. 84.) be equiangular to *abc*; which is impossible, since the triangle ABC is supposed equiangular to *abc*.

965. Prop. LXXXVI. *If four lines are proportional, their squares are also proportional.*

If the line AB be to the line AC as the line AD is to the line AF (*fig.* 319.), the square of the line AB will be to the square of the line AC as the square of the line AD is to the square of the line AF.

With the lines AB and AD form an angle BAD; with the lines AC and AF form another angle CAF equal to the angle BAD, and draw the right lines BD, CF.

Because AB is to AC as AD to AF, and the contained angles are equal, the two triangles BAD, CAF have their sides about equal angles proportional; they are therefore (Prop. 63.) equiangular, and consequently (Prop. 85.) similar: whence they are to one another (Prop. 82.) as the squares of their homologous sides. If, then, the triangle BAD be a third part of the triangle CAF, the square of the side AB will be a third part of the square of the side AC, and the square of the side AD will be a third part of the square of the side AF. Wherefore these four squares will be proportional.

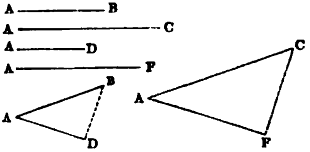


Fig. 319.

966. Prop. LXXXVII. *Similar rectilineal figures may be divided into an equal number of similar.*

Let the similar figures be ABCDF, *abcdf*, and draw the homologous lines CA, *ca*, CF, *cf*; these two figures will be divided into an equal number of similar triangles.

The triangles BCA, *bca* (*fig.* 320.), being composed of an equal number of corresponding points, are similar. The triangles ACF, *acf* and the triangles FCD, *fcd* are also, for the same reason, similar. Wherefore the similar figures ABCDF, *abcdf* are divided into an equal number of similar triangles.

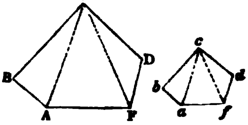


Fig. 320.

967. Prop. LXXXVIII. *Similar figures are equiangular.*

The similar figures ABCDF, *abcdf* (see *fig.* preced. Prop.) have their angles equal. Draw the homologous lines CA, *ca*, CF, *cf*. The triangles BCA, *bca* are similar, and consequently equiangular. Therefore the angle B is equal to the angle *b*, the angle BAC to the angle *bac*, and the angle BCA to the angle *bca*. The triangles ACF, *acf*, FCD, *fcd* are also equiangular, because they are similar. Therefore all the angles of the similar figures ABCDF, *abcdf* are equal.

968. Prop. LXXXIX. *Equiangular figures the sides of which are proportional are similar.*

If the figures ABCDF, *abcdf* (*fig.* 321.) have their angles equal and their sides proportional, they are similar. Draw the right lines CA, *ca*, CF, *cf*.

The triangles CBA, *cba*, have two sides proportional and the contained angle equal; they are therefore (Prop. 63.) equiangular, and consequently (Prop. 85.) similar. The lines CA, *ca* are therefore (Prop. 80.) proportional.

The triangles CAF, *caf* have two sides proportional and the contained angle equal; for if from the equal angles BAF, *baf* be taken the equal angles BAC, *bac*, there will remain the equal angles CAF, *caf*. These two triangles are therefore equiangular, and consequently similar. In the same manner it may be proved that the triangles CFD, *cfd* are similar.

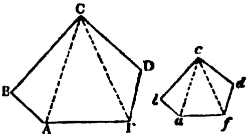


Fig. 321.

The two figures ABCDF, *abcdf* are then composed of an equal number of similar triangles; that is, they are composed of an equal number of points disposed in the same manner, or are similar.

PLANES.

969. Definitions. — 1. A plane is a surface, such that if a right line applied to it touches it in two points it will touch it in every other point. The surface of a fluid at rest, or of a well-polished table, may be considered as a plane.

2. A right line is *perpendicular* to a plane if it make right angles with all lines which can be drawn from any point in that plane. Thus BA (*fig.* 322.) is perpendicular to the plane MLGFPN, because it makes right angles with the lines AM, AL, AG, &c. drawn from the point A.

3. Let AB (*fig.* 323.) be the common intersection of two planes.

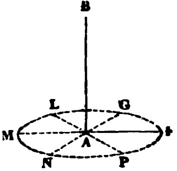


Fig. 322.

If two right lines LM, FG be drawn, in these two planes, perpendicular to the line AB, these will form four angles at the point C, which are called the *inclinations* of the two planes, or the angles formed by the two planes.

4. If the line AB (*fig.* 324.) revolves about itself, without changing its place, the line AC, which makes an acute angle with AB, will describe in the revolution a concave surface LAC; and the line AD, which makes an obtuse angle with AB, will describe in the revolution a convex surface MAD.

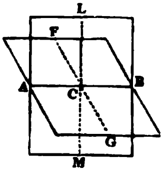


Fig. 323.

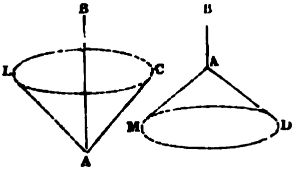


Fig. 324.

5. But the line AF (*fig.* Defin. 2.), which makes a right angle with AB, will describe in the revolution a surface which will be neither concave nor convex, but plane: and the line AB will be perpendicular to the plane MLGFPN, because it will make right angles with the lines AM, AL, AG, &c. drawn from the point A in that plane.

6. Two planes are *parallel* when all perpendiculars drawn from one to the other are equal. See *fig.* 325., wherein AB, CD are equal between the surfaces LM, FG.

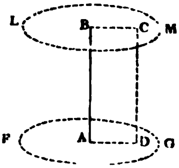


Fig. 325.

970. Prop. XC. *A perpendicular is the shortest line which can be drawn from any point to a plane.*

From the point B (*fig.* 326.), let the right line BA be drawn perpendicular to the plane DF; any other line, as BC, will be longer than the line BA. Upon the plane draw the right line AC.

Because the line BA is perpendicular to the plane DF, the angle BAC is a right angle. The square of BC is therefore (Prop. 32.) equal to the squares of BA and AC taken together. Consequently the square of BC is greater than the square of BA, and the line BC longer than the line BA.

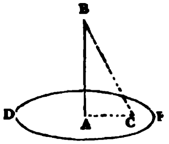


Fig. 326.

971. Prop. XCI. *A perpendicular measures the distance of any point from a plane.*

The distance of one point from another is measured by a right line, because it is the shortest line which can be drawn from one point to another. So the distance from a point to a line is measured by a perpendicular, because this line is the shortest which can be drawn from the point to the line. In like manner, the distance from a point to a plane must be measured by a perpendicular drawn from that point to the plane, because this is the shortest line which can be drawn from the point to the plane.

972. Prop. XCII. *The common intersection of two planes is a right line.*

Let the two planes ALBMA, AFBGA (*fig.* 327.) intersect each other; the line which is common to both is a right line. Draw a right line from the point A to the point B.

Because the right line AB touches the two planes in the points A and B, it will touch them (Defin. 1.) in all other points; this line therefore, is common to the two planes. Wherefore the common intersection of the two planes is a right line.

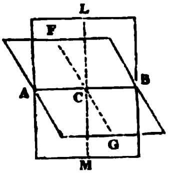


Fig. 327.

973. Prop. XCIII. *If three points, not in a right line, are common to two planes, these two planes are one and the same plane.*

Let two planes be supposed to be placed upon one another, in such manner that the three points A, B, C shall be common to the two planes; all their other points will also be common, and the two planes will be one and the same plane. The point D, for example, is common to both planes. Draw the right lines AB, CD.

Because the right line AB touches the two planes in the points A and B, it will touch them (Defin. 1.) in every other point; it will therefore touch them in the point F. The point F is therefore common to the two planes.

Again, because the right line CD touches the two planes in the points C and F, it will touch them in the point D; therefore the point D is common to the two planes. The same may be shown concerning every other point. Wherefore the two planes coincide in all points, or are one and the same plane.

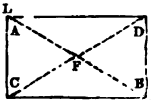


Fig. 328.

974. Prop. XCIV. *If a right line be perpendicular to two right lines which cut each other, it will be perpendicular to the plane of these right lines.*

Let the line AB (*fig.* 329.) make right angles with the lines AC, AD, it will be perpendicular to the plane which passes through these lines.

If the line AB were not perpendicular to the FDCG, another plane might be made to pass through the point A, to which the AB would be perpendicular. But this is impossible; for, since the angles BAC, BAD are right angles, this other plane (Defin. 2.) must pass through the points C, D; it would therefore (Prop. 93.) be the same with the plane FDCG, since these two planes would have three common points A, C, D.

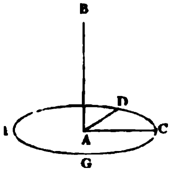


Fig. 329.

975. Prop. XCV. *From a given point in a plane to raise a perpendicular to that plane.*

Let it be required to raise a perpendicular from the point A (*fig.* 330.) in the plane LM.

Form a rectangle CDFG, divide it into two rectangles, having a common section AB, and place these rectangles upon the plane LM in such a manner that the bases of the two rectangles AC, AG shall be in the plane LM, and form any angle with each other; the line AB shall be perpendicular to the plane LM. The line AB makes right angles with the two lines AC, AG, which, by supposition, are in the plane LM; it is therefore (Prop. 94.) perpendicular to the plane LM.

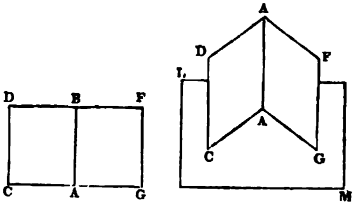


Fig. 330.

976. Prop. XCVI. *Two planes cutting each other at right angles, if a right line be drawn in one of the planes perpendicular to their common intersection, it will be perpendicular to the other plane.*

Let the two planes AFBG, ALBM (*fig.* 331.), cut each other at right angles; if the line LC be perpendicular to their common intersection, it is also perpendicular to the plane AFBG. Draw CG perpendicular to AB.

Because the lines CL, CG are perpendicular to the common intersection AB, the angle LCG (Defin. 3.) is the angle of inclination of the two planes. Since the two planes cut each other perpendicularly, the angle of inclination LCG is therefore a right angle.

And because the line LC is perpendicular to the two lines CA, CG in the plane ABFG, it is (Prop. 94.) perpendicular to the plane AFBG.

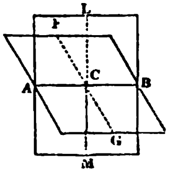


Fig. 331.

977. Prop. XCVII. *If one plane meet another plane, it makes angles with that other plane, which are together equal to two right angles.*

Let the plane ALBM (*fig.* 332.) meet the plane AFBG; these planes will make with each other two angles, which will together be equal to two right angles. Through any point C draw the lines FG, LM perpendicular to the line AB. The line CL makes with the line FG two angles together equal to two right angles. But these two angles are (Defin. 3.) the angles of inclination of the two planes. Therefore the two planes make angles with each other, which are together equal to two right angles.

Corollary. It may be demonstrated in the same manner that planes which intersect each other have their vertical angles equal, that parallel planes have their alternate angles equal, &c.

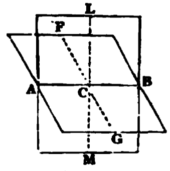


Fig. 332.

978. Prop. XCVIII. *If two planes be parallel to each other, a right line, which is perpendicular to one of the planes, will be also perpendicular to the other.*

Let the two planes LM, FG (*fig.* 333.) be parallel. If the line BA be perpendicular to the plane FG, it will also be perpendicular to the plane LM. From any point C in the plane LM draw CD perpendicular to the plane FG, and draw BC, AD.

Because the lines BA, CD are perpendicular to the plane FG, the angles A, D are right angles.

Because the planes LM, FG are parallel, the perpendiculars AB, DC (Defin. 6.) are equal; whence it follows that the lines BC, AD are parallel.

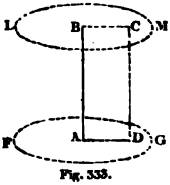


Fig. 333.

The line BA, being at right angles to the line AD, will also (Prop. 13.) be at right angles to the parallel line BC. The line BA is therefore perpendicular to the line BC.

In the same manner it may be demonstrated that the line BA is at right angles to all other lines which can be drawn from the point B in the plane LM. Wherefore (Defin. 2.) the line BA is perpendicular to the plane LM.

SOLIDS.

979. Definitions. — 1. A *solid*, as we have before observed, is that which has length, breadth, and thickness.

2. A *polyhedron* is a solid terminated by plane surfaces.

3. A *prism* is a solid terminated by two identical plane bases parallel to each other, and by surfaces which are parallelograms. (*Fig.* 334.)

4. A *parallelopiped* is a prism the bases of which are parallelograms. (*Fig.* 335.)

5. A *cube* is a solid terminated by six square surfaces: a die, for example, is a cube. (*Fig.* 336.)

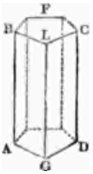


Fig. 334.

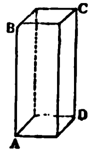


Fig. 335.

6. If right lines be raised from every point in the perimeter of any rectilineal figure, and meet in one common point, these lines together with the rectilineal figure inclose a solid which is called a *pyramid*. (*Fig.* 337.)

7. A *cylinder* is a solid terminated by two bases, which are equal and parallel circles, and by a convex surface; or it is a solid formed by the revolution of a parallelogram about one of its sides. (*Fig.* 338.)

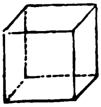


Fig. 336.

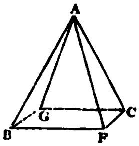


Fig. 337.

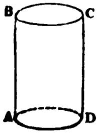


Fig. 338.

8. If right lines be raised from every point in the circumference of a circle, and meet in one common point, these lines together with the circle inclose a solid, which is called a *cone*. (*Fig.* 339.)

9. A semicircle revolving about its diameter forms a solid, which is called a *sphere*. (*Fig.* 340.)

10. If from the vertex of a solid a perpendicular be let fall upon the opposite plane, this perpendicular is called the *altitude* of the solid. In the pyramids ACD, A*cd* (*fig.* 341.), AB, *ab* are their respective altitudes.

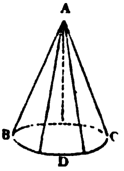


Fig. 339.

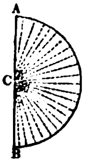


Fig. 340.

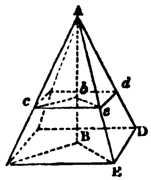


Fig. 341.

11. Solids are said to be *equal*, if they inclose an equal space: thus a cone and a pyramid are equal solids if the space inclosed within the cone be equal to the space inclosed within the pyramid.

12. *Similar solids* are such as consist of an equal number of physical points disposed in the same manner.

Thus (in the fig. Defin. 10.) the larger pyramid ACD and the smaller pyramid A*cd* are similar solids if every point in the larger pyramid has a point corresponding to it in the smaller pyramid. A hundred musket balls, and the same number of cannon balls, disposed in the same manner, form two similar solids.

980. Prop. XCIX. *The solid content of a cube is equal to the product of one of its sides twice multiplied by itself.*

Let the lines AB, AD (*fig.* 342.) be equal. Let the line AD, drawn perpendicular to AB, be supposed to move through the whole length of AB; when it arrives at BC, and coincides with it, it will have formed the square DABC, and will have been multiplied by the line AB.

Next let the line AF be drawn equal to AD, and perpendicular to the plane DABC; suppose the plane DABC to move perpendicularly through the whole length of the line AF; when it arrives at the plane MFGL, and coincides with it, it will have formed the cube AFLC, and will have been multiplied by the line AF.

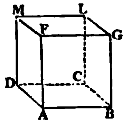


Fig. 342.

Hence it appears, that to form the cube AFLC, it is necessary, first, to multiply the side AD by the side AB equal to AD; and then to multiply the product, that is, the square of AC, by the side AF equal to AD; that is, it is necessary to multiply AD by AD, and to multiply the product again by AD.

981. Prop. C. *Similar solids have their homologous lines proportional.*

Let the two solids A, *a* (*fig.* 343.) be similar; and let their homologous lines be AB, *ab*, BG, *bg*; AB will be to BG at *ab* to *bg*.

Because the solids A, *a* are similar, every point in the solid A has a point corresponding to it, and disposed in the same

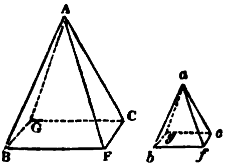


Fig. 343.

manner, in the solid *a*. Thus, if the line AB is composed of 20 physical points, and the line BG of 10, the line *ab* will be composed of 20 corresponding points, and the line *bg* of 10. Now it is evident that 20 is to 10 as 20 is to 10: therefore AB is to BG as *ab* to *bg*.

982. Prop. CI. *Similar solids are equiangular.*

Let the solids (see fig. to preced. Prop.) A, *a* be similar; their corresponding angles are equal.

Because the solids A, *a* are similar, the surfaces BAF, *baf* are composed of an equal number of points disposed in the same manner. These surfaces are therefore similar figures, and consequently (Prop. 88.) equiangular. The angles B, A, F are therefore equal to the angles *b*, *a*, *f*. In the same manner it may be demonstrated that the other correspondent angles are equal.

983. Prop. CII. *Solids which have their angles equal and their sides proportional are similar.*

If the solids A, *a* (*fig.* 344.) have their angles equal and their sides proportional, they are similar.

For if the solids A, *a* were not similar, another solid might be formed upon the line BF similar to the solid *a*. But this is impossible; for, in order to form this other solid, some angle or some side of the solid A must be increased or diminished; and then this new solid would not have all its angles equal and all its sides proportional to those of the solid *a*, that is (Prop. 100, 101.), would not be similar.

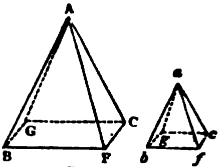


Fig. 344.

984. Prop. CIII. *Similar solids are to one another as the cubes of their homologous sides.*

Let A, *a* (see fig. to preced. Prop.) be two similar solids, the solid A contains the solid *a* as many times as the cube formed upon the side BF contains the cube formed upon the side *bf*.

Because the solid A is similar to the solid *a*, every point in the solid A has its corresponding point in the solid *a*. From whence it follows, that if the side BF is composed, for example, of 50 points, the side *bf* will also be composed of 50 points: and consequently the cubes formed upon the sides BF, *bf* will be composed of an equal number of points.

Let it then be supposed that the solid A is composed of 4000 points, and the cube of the side BF of 5000 points; the solid A must be composed of 4000 points, and the cube of the side *bf* of 5000 points. Now it is evident that 4000 is to 5000 as 4000 to 5000. Wherefore the solid A is to the cube of BF as the solid *a* to the cube of *bf*; and, alternately, the solid A is to the solid *a* as the cube of BF to the cube of *bf*.

Corollary. It may be demonstrated in the same manner that the spheres A, *a* (*fig.* 345.), which are similar solids, are to one another as the cubes of their radii AB, *ab*.

985. Prop. CIV. *The solid content of a perpendicular prism is equal to the product of its base and height.*

The solid content of the perpendicular prism ABCD (*fig.* 346.) is equal to the product of its base AD, and height AD.

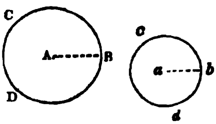


Fig. 345

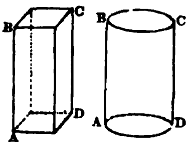


Fig. 346.

If the lower base AD be supposed to move perpendicularly along the height AB till it coincides with the upper base BC, it will have formed the prism ABCD. Now the base AD will have been repeated as many times as there are physical points in the height AB. Therefore the solid content of the prism ABCD is equal to the product of the base multiplied by the height.

Corollary. In the same manner it may be demonstrated that the solid content of the perpendicular cylinder ABCD is equal to the product of its base AD and height AB.

986. Prop. CV. *The solid content of an inclined prism is equal to the product of its base and height.*

Let the inclined prism be CP (*fig.* 347.), it is equal to the product of its base RP and its height CD.

Conceive the base NB of the perpendicular prism NA, and the base RP of the inclined prism PC, to move on in the same time parallel to themselves; when they have reached the points A and C, each of them will have been taken over again the same number of times. But the base NB will have been taken over again (Prop. 104.) as many times as there are physical points in the height CD. The base RP will therefore have been taken over again as many times as there are physical points in CD. Consequently the solid content of the inclined prism CP is equal to the product of its base RP and the height CD.

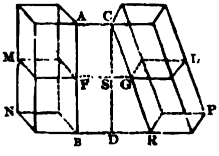


Fig. 347.

987. PROP. CVI. *In a pyramid, a section parallel to the base is similar to the base.*

Let the section *cd* be parallel to the base CD (*fig.* 348.); this section is a figure similar to the base. Draw AB perpendicular to the base CD; draw also BC, *bc*, BE, *be*.

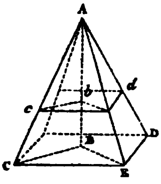


Fig. 348.

Because the planes *cd* CD are parallel; AB, being perpendicular to the plane CD, will also (Prop. 98.) be perpendicular to the plane *cd*: whence the triangles A*bc*, ABC, having the angles *b*, B right angles, and the angle A common, are equiangular. Therefore (Prop. 61.) A*b* is to AB as *bc* to BC, and as A*c* to AC.

In like manner it may be proved that A*b* is to AB as *be* to BE, and as A*e* to AE. Consequently if A*b* be one third part of AB, *bc* will be one third part of BC, *be* the same of BE, A*c* of AC, and A*e* of AE.

Again, in the two triangles *c*A*e*, CAE, there are about the angle A, common to both, two sides proportional; they are therefore (Prop. 63.) equiangular, and consequently (Prop. 61.) have their other sides proportional. Therefore *ce* will be one third part of CE.

The two triangles *cbe* CBE, having their sides proportional, are therefore (Prop. 89.) similar. The same may be demonstrated concerning all the other triangles which form the planes *cd*, CD. Therefore the section *cd* is similar to the base CD.

REMARK. If the perpendicular AB fall out of the base; by drawing lines from the points *b*, B, it may be demonstrated in the same manner that the section is similar to the base.

988. PROP. CVII. *In a pyramid, sections parallel to the base are to one another as the squares of their heights.*

Let CD *cd* (*fig.* 349.) be parallel sections. From the vertex A draw a perpendicular AB to the plane CD: the plane *cd* is to the plane CD as the square of the height A*b* is to the square of the height AB. Draw BC, *bc*.

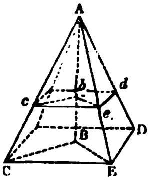


Fig. 349.

The line AB, being perpendicular to the plane CD, will also (Prop. 98.) be perpendicular to the parallel plane *cd*: whence the angle A*bc* is a right angle, and also the angle ABC. Moreover, the angle at A is common to the two triangles A*bc*, ABC; these two triangles, therefore, are equiangular. Therefore (Prop. 61.) the side *cb* is to the side CB as the side A*b* is to the side AB; and consequently the square of *cb* is to the square of CB as the square of A*b* to the square of AB.

The planes *cd*, CD, being (Prop. 106.) similar figures, are to one another (Prop. 82.) as the squares of the homologous lines *cb*, CB; they are therefore also as the squares of the heights A*b*, AB.

COROLLARY. In the same manner it may be demonstrated that in a cone the sections parallel to the base are to one another as the squares of the heights or perpendicular distances from the vertex.

989. PROP. CVIII. *Pyramids of the same height are to one another as their bases.*

Let A, F (*fig.* 350.) be two pyramids. If the perpendicular AB be equal to the perpendicular FG, the pyramid A is to the pyramid F as the base CD to the base LM. Supposing, for example, the base CD to be triple of the base LM, the pyramid A will be triple of the pyramid F.

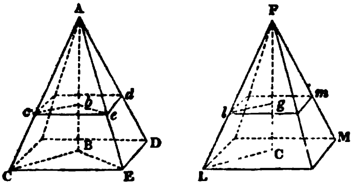


Fig. 350.

Two sections *cd*, *lm*, being taken at equal heights A*b*, F*g*, the section *cd* is (Prop. 107.) to the base CD as the square of the height A*b* to the square of the height AB; and the section *lm* is to the base LM as the square of the height F*g* to the square of the height FG. And because the heights are equal, AB to FG, and A*b* to F*g*, the section *cd* is to the base CD as the section *lm* to the base LM; and, alternately, the section *cd* is to the section *lm* as the base CD is to the base LM. But the base CD is triple of the base LM, therefore the section *cd* is also triple of the section *lm*.

Because the heights AF, FG are equal, it is manifest that the two pyramids are composed of an equal number of physical surfaces placed one upon another. Now it may be demonstrated in the same manner that every surface or section of the pyramid A is triple of the corresponding surface or section of the pyramid F. Therefore the whole pyramid A is triple of the whole pyramid F.

COROLLARY. Pyramids of the same height and equal bases are equal, since they are to one another as their bases.

990. PROP. CIX. *A pyramid whose base is that of a cube and whose vertex is at the centre of the cube is equal to a third part of the product of its height and base.*

Let the cube AM and the pyramid C (*fig.* 351.) have the same base AD, and let the vertex of the pyramid be at the centre of the cube C; this pyramid is equal to a third part of the product of its height and base.

Conceive right lines drawn from the centre of the cube to its eight angles A, B, D, F, N, G, L, M, the cube will be divided into six equal pyramids, each of which has one surface of the cube for its base, and half the height of the cube for its height; for example, the pyramid CABDF.

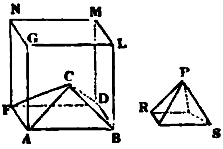


Fig. 351.

Three of these pyramids will therefore be equal to half the cube. Now the solid content of half the cube is (Prop. 99.) equal to the product of the base and half the height. Each pyramid, therefore, will be equal to one third part of the product of the base, and half the height of the cube; that is, the whole height of the pyramid.

991. Prop. CX. *The solid content of a pyramid is equal to a third part of the product of its height and base.*

Let RPS (*fig.* 352.) be a pyramid, its solid content is equal to a third part of the product of its height and its base RS.

Form a cube the height of which BL is double of the height of the pyramid RPS. A pyramid the base of which is that of this cube and the vertex of which is C, the centre of the cube, will be equal to a third part of the product of its base and height.

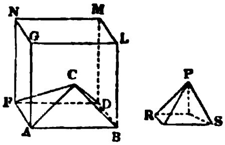


Fig. 352.

The pyramids C and P have the same height; they are therefore (Corol. to Prop. 108.) to one another as their bases. If the base AFDB is double of the base RS, the pyramid C will therefore be double of the pyramid P.

But the pyramid C is equal to a third part of the product of its height and base. The pyramid P will therefore be equal to a third part of the product of the same height, and half the base AFDB, or, which is the same thing, the whole base RS.

992. Prop. CXI. *The solid content of a cone is equal to the third part of the product of its height and base.*

For the base of a cone may be considered as a polygon composed of exceedingly small sides, and consequently the cone may be considered as a pyramid having a great number of exceedingly small surfaces; whence its solid contents will be equal (Prop. 110.) to one third part of the product of its height and base.

993. Prop. CXII. *The solid content of a cone is a third part of the solid content of a cylinder described about it.*

Let the cone BAC and the cylinder BDFC (*fig.* 353.) have the same height and base, the cone is a third part of the cylinder.

For the cylinder is equal to the product of its height and base, and the cone is equal to a third part of this product. Therefore the cone is a third part of the cylinder.

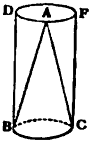


Fig. 353.

994. Prop. CXIII. *The solid content of a sphere is equal to a third part of the product of its radius and surface.*

Two points not being sufficient to make a curve line, three points will not be sufficient to make a curve surface. If, therefore, all the physical points which compose the surface of the sphere C (*fig.* 354.) be taken three by three, the whole surface will be divided into exceedingly small plane surfaces; and radii being drawn to each of these points, the sphere will be divided into small pyramids, which have their vertex at the centre, and have plane bases.

The solid contents of all these small pyramids will be equal (Prop. 110.) to a third part of the product of the height and bases. Therefore the solid content of the whole sphere will be equal to a third part of the product of the height and all the bases, that is, of its radius and surface.

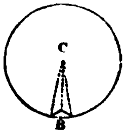


Fig. 354.

995. Prop. CXIV. *The surface of a sphere is equal to four of its great circles.*

If a plane bisect a sphere, the section will pass through the centre, and it is called a great circle of the sphere.

Let ABCD (*fig.* 355.) be a square; describe the fourth part of the circumference of a circle BLD; draw the diagonal AC, the right line FM, parallel to AD, and the right line AL.

In the triangle ABC, on account of the equal sides AB, BC, the angles A and C are (Prop. 4.) equal; therefore, since the angle B is a right angle, the angles A and C are each half a right angle. Again, in the triangle AFG, because the angle F is a right angle, and the angle A half a right angle, the angle G is also half a right angle; therefore (Prop. 26.) AF is equal to FG.

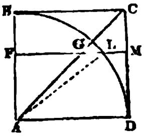


Fig. 355.

The radius AL is equal to the radius AD: but AD is equal to FM; therefore AL is equal to FM.

In the rectangular triangle AFL the square of the hypothenuse AL is equal (Prop. 32.) to the two squares of AF and FL taken together. Instead of AL put its equal FM, and instead of AF put its equal FG; and the square of FM will be equal to the two squares of FG and FL taken together.

Conceive the square ABCD to revolve about the line AB. In the revolution the square will describe a cylinder, the quadrant a hemisphere, and the triangle ABC an inverted cone the vertex whereof will be in A. Also the line FM will form a circular section of a cylinder, the line FL will form a circular section of a hemisphere, and the line FG a circular section of a cone.

These circular sections, or circles, are to each other (Prop. 83.) as the squares of their radii; therefore, since the square of the radius FM is equal to the squares of the radii FL and FG, the circular section of the cylinder will be equal to the circular sections of the hemisphere and cone.

In the same manner it may be demonstrated that all the other sections or circular surfaces whereof the cylinder is composed are equal to the corresponding sections or surfaces of the hemisphere and cone. Therefore the cylinder is equal to the hemisphere and cone taken together: but the cone (Prop. 112.) is equal to a third part of the cylinder; the hemisphere is therefore equal to the remaining two thirds of the cylinder; and consequently the hemisphere is double of the cone. The cone BSC, (*fig.* 356.) is (Prop. 111.) equal to a third part of the product of the radius and base BC, which is a great circle of the sphere: the hemisphere ALD is therefore equal to a third part of the product of the radius and two of its great circles; and consequently the whole sphere is equal to a third part of the product of the radius and four of its great circles.

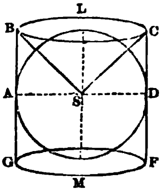


Fig. 356.

Lastly, since the sphere is equal (Prop. 113.) to a third part of the product of the radius and surface of the sphere, and also to a third part of the product of the radius and four of its great circles, the surface of the sphere is equal to four of its great circles.

Sect. III.

PRACTICAL GEOMETRY.

996. Practical Geometry is the art of accurately delineating on a plane surface any plane figure. It is the most simple species of geometrical drawing, and the most generally useful; for the surfaces of buildings and other objects are more frequently plane than curved, and they must be drawn with truth, and of the required proportions, before they can be properly executed, unless in cases where the extreme simplicity of the form renders it improbable that mistakes should arise. It has been defined as the art which directs the mechanical processes for finding the position of points, lines, surfaces, and planes, with the description of such figures on diagrams as can be intelligibly understood by definition, according to given dimensions and positions of lines, points, &c.

No part of a building or drawing can be laid down or understood without the assistance of practical geometry, nor can any mechanical employment in the building department be conducted without some assistance from this branch of the science. Cases frequently occur requiring a knowledge of very complex problems, as in masonry, carpentry, and joinery; but these will be given in other parts of this work.

The demonstration of most of the following problems will be found in the preceding section; we therefore refer the reader back to it for definitions, and for the proof of those enunciations which will follow.

PROBLEMS.

997. Problem I. *To bisect a line* AB; *that is, to divide it into two equal parts.*

From the two centres A and B (*fig.* 357.) with any equal radii describe arcs of circles intersecting each other in C and D, and draw the line CD. This will bisect the given line in the point E.

998. Prob. II. *To bisect an angle* BAC.

From the centre A (*fig.* 358.) with any radius describe an arc cutting off the equal lines AD, AE; and from the two centres D, E, with the same radius describe arcs intersecting in F, then draw AF, and it will bisect the angle A, as required.

999. Prob. III. *At a given point* C *in a line* AB *to erect a perpendicular.*

From the given point C (*fig.* 359.) with any radius cut off any equal parts CD, CE of the given line; and from the two centres D and E with any one radius describe arcs intersecting in F. Then join CF, and it will be the perpendicular required.

Otherwise — When the given point C is near the end of the line.

From any point D (*fig.* 360.) assumed above the line as a centre, through the given point C describe a circle cutting the given line at E, and through E and the centre D draw the diameter EDF; then join CF, and it will be the perpendicular required.

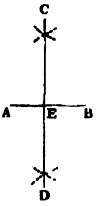


Fig. 357.

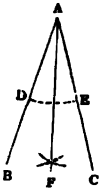


Fig. 358.

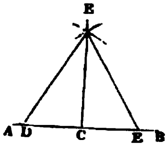


Fig. 359.

1000. Prob. IV. *From a given point* A *to let fall a perpendicular on a line* BC.

From the given point A (*fig.* 361.) as a centre with any convenient radius describe an arc cutting the given line at two points D and E; and from the two centres D and E with any radius describe two arcs intersecting at F; then draw AGF, and it will be the perpendicular to BC required.

Otherwise — When the given point is nearly opposite the end of the line.

From any point D in the given line BC (*fig.* 362.) as a centre, describe the arc of a circle through the given point A cutting BC in E; and from the centre E with the radius EA describe another arc cutting the former in F; then draw AGF, which will be the perpendicular to BC required.

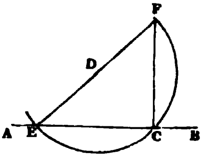


Fig. 360.

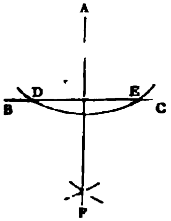


Fig 361.

1001. Prob. V. *At a given point* A, *in a line* AB, *to make an angle equal to a given angle* C.

From the centres A and C (*fig.* 363.) with any radius describe the arcs DE, FG; then with F as a centre, and radius DE, describe an arc cutting FG in G; through G draw the line AG, which will form the angle required.

1002. Prob. VI. *Through a given point* C *to draw a line parallel to a given line* AB.

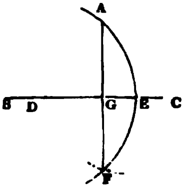


Fig. 362.

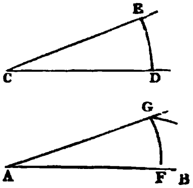


Fig. 363.

Case I.

Take any point *d* in AB (*fig.* 364.); upon *d* and C, with the distance C*d*, describe two arcs, *e*C and *df*, cutting AB in *e* and *d*. Make *df* equal to *e*C; and through C*f* draw C*f*, and it will be the line required.

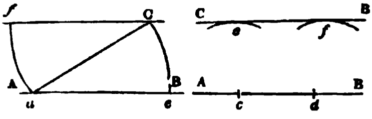


Fig. 364.

Case II.

When the parallel is to be drawn at a given distance from AB.

From any two points *c* and *d* in the line AB, with a radius equal to the given distance describe the arcs *e* and *f*; draw the line CB to touch those arcs without cutting them, and it will be parallel to AB, as required.

1003. Prob. VII. *To divide a line* AB *into any proposed number of equal parts.*

Draw any other line AC (*fig.* 365.), forming any angle with the given line AB; on the latter set off as many of any equal parts AD, DE, EF, FC as those into which the line AB is to be divided; join BC, and parallel thereto draw the other lines FG, EH, DI; then these will divide AB, as required.

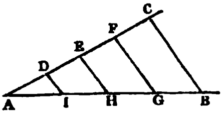


Fig. 365.

1004. Prob. VIII. *To find a third proportional to two other lines* AB, AC.

Let the two given lines be placed to form any angle at A (*fig.* 366.), and in AB take AD equal to AC; join BC, and draw DE parallel to it; then AE will be the third proportional sought.

1005. Prob. IX. *To find a fourth proportional to three lines* AB, AC, AD.

Let two of the lines AB, AC (*fig.* 367.), be so placed as to form any angle at A, and set out AD or AB; join BC, and parallel to it draw DE; then AE will be the fourth proportional required.

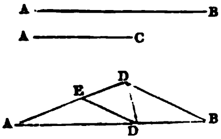


Fig. 366.

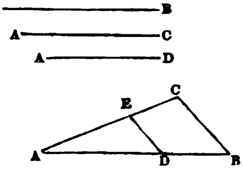


Fig. 367.

1006. Prob. X. *To find a mean proportional between two lines* AB, BC.

Place AB, BC (*fig.* 368.) joined together in one straight line AC, which bisect in the point O; then with the centre O and radius OA or OC describe the semicircle ADC, to meet which erect the perpendicular BD, which will be the mean proportional between AB and BC sought.

1007. Prob. XI. *To find the centre of a circle.*

Draw any chord AB (*fig.* 369.), and bisect perpendicularly with the line CD, which bisected in O will be the centre required.

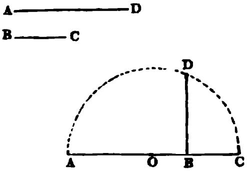


Fig. 368.

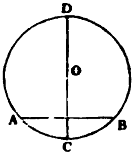


Fig. 369.

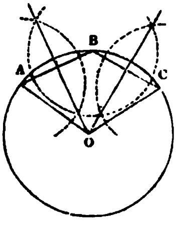


Fig. 370.

1008. Prob. XII. *To describe the circumference of a circle through three points* A, B, C.

From the middle point B (*fig.* 370.) draw the chords BA, BC to the two other points, and bisect these chords perpendicularly by lines meeting in O, which will be the centre; from the centre O, with the distance of any one of the points, as OA, describe a circle, and it will pass through the two other points B, C, as required.

1009. Prob. XIII. *To draw a tangent to a circle through a given point* A.

When the given point A (*fig.* 371.) is in the circumference of the circle, join A and the centre O, and perpendicular thereto draw BAC, which will be the tangent required.

If the given point A (*fig.* 372.) be out of the circle, draw AO to the centre O, on which, as a diameter, describe a semicircle cutting the given circumference in D, through which draw BADC, which will be the tangent required.

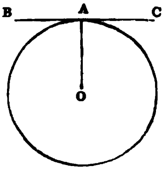


Fig. 371.

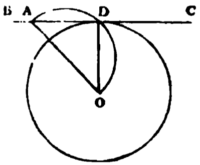


Fig. 372.

1010. Prob. XIV. *To draw an equilateral triangle on a given line* AB.

From the centres A and B (*fig.* 373.) with the distance AB describe arcs intersecting in C; draw AC, BC, and ABC will be the equilateral triangle.

1011. Prob. XV. *To make a triangle with three given lines* AB, AC, BC.

With the centre A and distance AC (*fig.* 374.) describe an arc; with the centre B and distance BC describe another arc cutting the former in C; draw AC, BC, and ABC will be the triangle required.

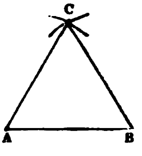


Fig. 373.

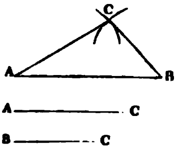


Fig. 374.

1012. Prob. XVI. *To make a square on a given line* AB.

Raise AD, BC (*fig.* 375.) each perpendicular and equal to AB, and join DC; then ABCD will be the square sought.

1013. Prob. XVII. *To inscribe a circle in a given triangle* ABC.

Bisect the angles at A and B with the two lines AD, BD (*fig.* 376.); from the intersection D, which will be the centre of the circle, draw the perpendiculars DE, DF, DG, and they will be the radii of the circle required.

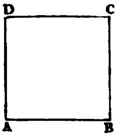


Fig. 375.

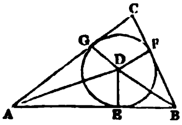


Fig. 376.

1014. Prob. XVIII. *To describe a circle about a given triangle* ABC.

Bisect any two sides with two of the perpendiculars DE, DF, DG (*fig.* 377.), and D will be the centre of the circle.

1015. Prob. XIX. *To inscribe an equilateral triangle in a given circle.*

Through the centre C draw any diameter AB (*fig.* 378.); from the point B as a centre, with the radius BC of the given circle, describe an arc DCE; join AD, AE, DE, and ADE is the equilateral triangle sought.

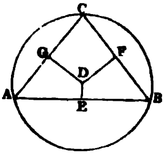


Fig. 377.

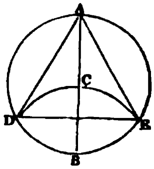


Fig. 378.

1016. Prob. XX. *To inscribe a square in a given circle.*

Draw two diameters AC, BD (*fig.* 379.) crossing at right angles in the centre E; then join the four extremities A, B, C, D with right lines, and these will form the inscribed square ABCD.

1017. Prob. XXI. *To describe a square about a given circle.*

Draw two diameters AC, BD crossing at right angles in the centre E (*fig.* 380.); then through the four extremities of these draw FG, IH parallel to AC, and FI, GH parallel to BD, and they will form the square FGHI.

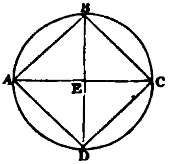


Fig. 379.

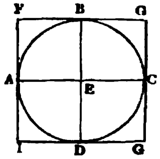


Fig. 380.

1018. Prob. XXII. *To inscribe a circle in a given square.*

Bisect the two sides FG, FI in the points A and B (see *fig.* 380.); then through these two points draw AC parallel to FG or IH, and BD parallel to FI or GH. Then the point of intersection E will be the centre, and the four lines EA, EB, EC, ED radii of the inscribed circle.

1019. Prob. XXIII. *To cut a given line in extreme and mean ratio.*

Let AB be the given line to be divided in extreme and mean ratio (*fig.* 381.); that is, so that the whole line may be to the greater part as the greater part is to the less part.

Draw BC perpendicular to AB, and equal to half AB; join AC, and with the centre C and distance CB describe the circle BD; then with the centre A and distance AD describe the arc DE. Then AB will be divided in E in extreme and mean ratio, or so that AB is to AE as AE is to EB.

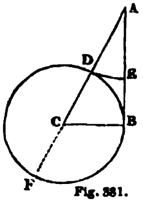


Fig. 381.

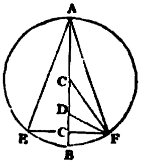


Fig. 382.

1020. Prob. XXIV. *To inscribe an isosceles triangle in a given circle that shall have each of the angles at the base double the angle at the vertex.*

Draw any diameter AB of the given circle (*fig.* 382.), and divide the radius CB in the point D in extreme and mean ratio (by the last problem); from the point B apply the chords BE, BF, each equal to the greater part CD; then join AE, AF, EE; and AEF will be triangle required.

1021. Prob. XXV. *To inscribe a regular pentagon in a given circle.*

Inscribe the isosceles triangle AB (*fig.* 383.) having each of the angles ABC, ACB double the angle BAC (Prob. 24.); then bisect the two arcs ADB, AEC, in the points D, E; and draw the chords AD, DB, AE, EC; then ADBCE will be the inscribed equilateral triangle required.

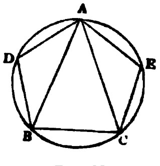


Fig. 383.

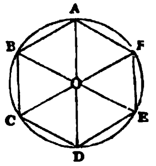


Fig. 384.

1022. Prob. XXVI. *To inscribe a regular hexagon in a circle.*

Apply the radius of the given circle AO as a chord (*fig.* 384.) quite round the circumference, and it will form the points thereon of the regular hexagon ABCDEF.

1023. Prob. XXVII. *To describe a regular pentagon or hexagon about a circle.*

In the given circle inscribe a regular polygon of the same name or number of sides as ABCDE (*fig.* 385.) by one of the foregoing problems; then to all its angular points draw (Prob. 13.) tangents, and these will by their intersections form the circumscribing polygon required.

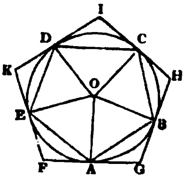


Fig. 385.

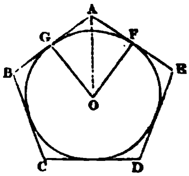


Fig. 386.

1024. **PROB. XXVIII.** *To inscribe a circle in a regular polygon.*

Bisect any two sides of the polygon by the perpendiculars GO, FO (*fig.* 386.), and their intersection O will be the centre of the inscribed circle, and OG or OF will be the radius.

1025. **PROB. XXIX.** *To describe a circle about a regular polygon.*

Bisect any two of the angles C and D with the lines CO, DO (*fig.* 387.), then their intersection O will be the centre of the circumscribing circle; and OC or OD will be the radius.

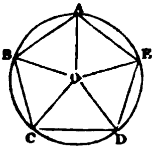


Fig. 387.

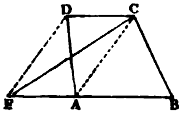


Fig. 388.

1026. **PROB. XXX.** *To make a triangle equal to a given quadrilateral* ABCD.

Draw the diagonal AC (*fig.* 388.), and parallel to it DE, meeting BA produced at E, and join CE; then will the triangle CEB be equal to the given quadrilateral ABCD.

1027. **PROB. XXXI.** *To make a triangle equal to a given pentagon* ABCDE.

Draw DA and DB, and also EF, CG parallel to them (*fig.* 389.), meeting AB produced at F and G; then draw DF and DG, so shall the triangle DFG be equal to the given pentagon ABCDE.

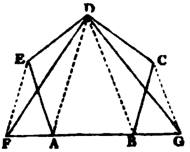


Fig. 389.

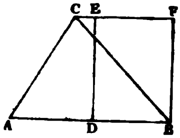


Fig. 390.

1028. **PROB. XXXII.** *To make a rectangle equal to a given triangle* ABC.

Bisect the base AB in D (*fig.* 390.), then raise DE and BF perpendicular to AB, and meeting CF parallel to AB at E and F. Then DF will be the rectangle equal to the given triangle ABC.

1029. **PROB. XXXIII.** *To make a square equal to a given rectangle* ABCD.

Produce one side AB till BE be equal to the other side BC (*fig.* 391.). On AE as a diameter describe a circle meeting BC produced at F, then will BF be the side of the square BFGH equal to the given rectangle BD, as required.

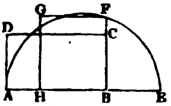


Fig. 391.

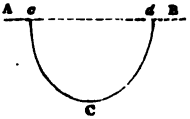


Fig. 392.

1030. **PROB. XXXIV.** *To draw a catenary.*

A catenary being a curve into which a perfectly flexible cord or chain will arrange itself when suspended by its two extremities, it may thus be described. Let AB (*fig.* 392.) be a given line from two points *c*, *d*, whereof the curve is to fall, and let C be the lowest point in the curve. From two pins inserted at the points *c* and *d* suspend a fine cord or chain, lengthening it till the lowest point of the crown touches C, then a pencil tracing its line on the paper; the curve thus formed will be the catenary required.

1031. **PROB. XXXV.** *To draw a cycloid.*

If the circumference of a circle be rolled along a right line AB (*fig.* 393.) until any point *b*, *b* in the circumference which was in contact with the line come again in contact with it, the point *b* will describe a curve called a cycloid. Let the circle be BC, and the semi-base be AB, which must be equal to the semi-circumference of the circle. Draw any chords C*b*, C*b*, and parallel to AB draw the horizontal lines *ab*, *ab*, making them respectively equal to the length of the arcs cut off by the chords. Then through the points *a*, *a*, so obtained, draw a curve line, and it will be the cycloid required.

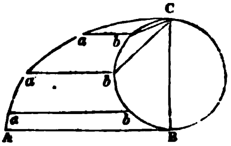


Fig. 393.

1032. **PROB. XXXVI.** *To draw a diagonal scale.*

Let it be of feet, tenths and hundredth parts of a foot. Set off on AB (*fig.* 394.) as many times as necessary, the number of feet by equal distances. Divide AG into ten equal parts. On AB raise the perpendiculars BD, GG, and AC, and set off on AC ten equal divisions of any convenient length, through which draw horizontal lines. Then, from the point G in DC to the first tenth part from G to A in BA draw a diagonal, and parallel thereto the other diagonals required. The intersections of these diagonals with the horizontal lines give hundredth parts of a foot, inasmuch as each tenth is divided by the diagonals into ten equal parts in descending.

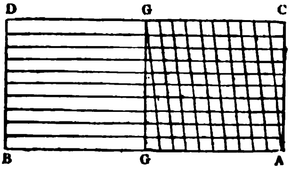


Fig. 394.

Sect. IV.

PLANE TRIGONOMETRY.

1033. Plane Trigonometry is that branch of mathematics whose object is the investigation and calculation of the sides and angles of plane triangles. It is of the greatest importance to the architect in almost every part of his practice; but the elements will be sufficient for his use, without pursuing it into those more abstruse subdivisions which are essential in the more abstract relations which connect it with geodisic operations.

1034. We have already observed that every circle is supposed to be divided into 360 equal parts, called degrees, and that each degree is subdivided into 60 minutes, these minutes each into 60 seconds, and so on. Hence a semicircle contains 180 degrees, and a quadrant 90 degrees.

1035. The measure of an angle is that arc of a circle contained between those two lines which form the angle, the angular point being the centre, and such angle is estimated by the number of degrees contained in the arc. Thus, a right angle whose measure is a quadrant or quarter of the circle is one of 90 degrees (Prop. 22. Geometry); and the sum of the three angles of every triangle, or two right angles, is equal to 180 degrees. Hence in a right-angled triangle, one of the acute angles being taken from 90 degrees, the other acute angle is known; and the sum of two angles in a triangle taken from 180 degrees leaves the third angle; or either angle taken from 180 degrees leaves the sum of the other two angles.

1036. It is usual to mark the figure which denotes degrees with a small °: thus, 60° means 60 degrees; minutes are marked thus ′: hence, 45′ means 45 minutes; seconds are marked thus ″, 49″ meaning 49 seconds; and an additional comma is superadded for thirds, and so on. Thus, 58° 14′ 25″ is read 58 degrees, 14 minutes, 25 seconds.

1037. The *complement* of an arc is the quantity it wants of 90 degrees. Thus, AD (*fig.* 395.) being a quadrant, BD is the complement of the arc AB, and, reciprocally, AB is the complement of BD. Hence, if an arc AB contain 50 degrees, its complement BD will be 40.

1038. The *supplement* of an arc is that which it wants of 180 degrees. Thus, ADE being a semicircle, BDE is the supplement of the arc AB, which arc, reciprocally, is the supplement of BDE. Thus, if AB be an arc of 50 degrees, then its supplement BDE will be 130 degrees.

1039. The line drawn from one extremity of an arc perpendicular to a diameter passing through its other extremity is called a *sine* or *right sine*. Thus, BF is the sine of the arc AB, or of the arc BDE. Hence the sine (BF) is half the chord (BG) of the double arc (BAG).

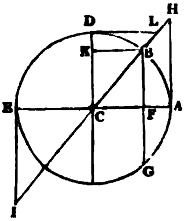


Fig. 395.

1040. That part of the diameter intercepted between the arc and its sine is called the *versed sine* of an arc. Thus, AF is the versed sine of the arc AB, and EF the versed sine of the arc EDB.

1041. The *tangent* of an arc is a line which touches one end of the arc, continued from thence to meet a line drawn from the centre, through the other extremity, which last line is called the *secant* of the arc. Thus, AH is the tangent and CH the secant of the arc AB. So EI is the tangent and CI the secant of the supplemental arc BDE. The latter tangent and secant are equal to the former; but, from being drawn in a direction opposite or contrary to the former, they are denominated *negative*.

1042. The *cosine* of an arc is the right sine of the complement of that arc. Thus BF, the sine of AB, is the cosine of BD.

1043. The *cotangent* of an arc is the tangent of that arc's complement. Thus AH, which is the tangent of AB, is the cotangent of BD.

1044. The *cosecant* of an arc is the secant of its complement. Thus CH, which is the secant of AB, is the cosecant of BD.

1045. From the above definitions follow some remarkable properties.

I. That an arc and its supplement have the same sine, tangent, and secant; but the two latter, that is, the tangent and the secant, are accounted negative when the arc exceeds a quadrant, or 90 degrees. II. When the arc is 0, or nothing; but the secant then becomes the radius CA, which is the least it can be. As the arc increases from 0, the sines, tangents, and secants all increase, till the arc becomes a whole quadrant AD, and then the sine is the greatest it can be, being equal to the radius of the circle; under which circumstance the tangent and secant are infinite. III. In every arc AB, the versed sine AF, and the cosine BK or CF, are together equal to the radius of the circle. The radius CA, the tangent AH, and the secant CH, form a right-angled triangle CAH. Again, the radius, sine, and cosine form another right-angled triangle CBF or CBK. So also the radius, cotangent, and cosecant form a right-angled triangle CDL. All these right-angled triangles are similar to each other.

1046. The sine, tangent, or secant of an angle is the sine, tangent, or secant of the arc by which the angle is measured, or of the degrees, &c. in the same arc or angle. The method of constructing the scales of chords, sines, tangents, and secants engraved on mathematical instruments is shown in the annexed figure.

1047. A trigonometrical canon (*fig.* 396.) is a table wherein is given the length of the sine, tangent, and secant to every degree and minute of the quadrant, compared with the radius, which is expressed by unity or 1 with any number of ciphers. The logarithms, moreover, of these sines, tangents, and secants, are tabulated, so that trigonometrial calculations are performed by only addition and subtraction. (See 632. *et seq.*) Tables of this sort are published separately, and we suppose the reader to be provided with such.

1048. PROBLEM I. *To compute the natural sine and cosine of a given arc.*

The semiperiphery of a circle whose radius is 1 is known to be 3·14159265358979З, &c.: we have then the following proportion: —

As the number of degrees or minutes in the semicircle
Is to the degrees or minutes in the proposed arc,
So is 3·14159265, &c. to the length of the said arc,

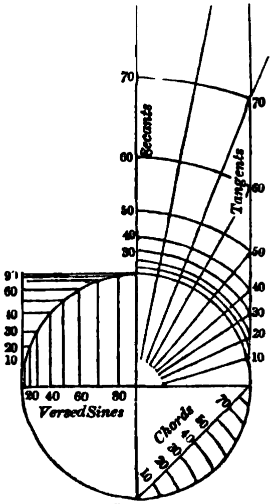


Fig. 396.

Now the length of the arc being denoted by the letter a, and its sine and cosine by s and c, these two will be expressed by the two following series, viz. —

$$s = a - \frac{a^3}{2\cdot3} + \frac{a^5}{2.3.4.5} - \frac{a^7}{2.3.4.5.6.7} + \&c.$$

$$= a - \frac{a^3}{6} + \frac{a^5}{120} - \frac{a^7}{5040} + \&c.$$

$$c = 1 - \frac{a^2}{2} + \frac{a^4}{2.3.4} - \frac{a^6}{2.3.4.5.6} + \&c.$$

$$= 1 - \frac{a^2}{2} + \frac{a^4}{24} - \frac{a^6}{720} + \&c.$$

Example 1. Let it be required to find the sine and cosine of one minute. The number of minutes in 180 degrees being 10800, it will be, first, as 10800 : 1 : : 3·14159265, &c. : ·000290888208665 = the length of an arc of one minute. Hence, in this case,—

$a =$ ·0002908882
and $\frac{1}{6}a^3 =$ ·000000000004
The difference is $s =$ ·0002908882, the sine of one minute.
Also from 1.
take $\frac{1}{2}a^2 =$ 0·0000000423079, &c.
leaves $c =$ ·9999999577, the cosine of one minute.

Example 2. For the sine and cosine of 5 degrees: —

Here 180° : 5° : : 3·14159265, &c. : ·08726646 $= a$, the length of 5 degrees.
Hence $a =$ ·08726646
$-\frac{1}{6}a^3 =$ ·00011076
$+\frac{1}{120}a^5 =$ ·00000004

These collected give $s =$ ·08715574, the sine of 5 degrees.

And for the cosine 1 = 1·
$-\frac{1}{2}a^2 =$ ·00380771
$+\frac{1}{24}a^4 =$ ·00000241

These collected give $c =$ ·99619470, the cosine of 5 degrees.

In the same way we find the sines and cosines of other arcs may be computed. The greater the arc the slower the series will converge; so that more terms must be taken to make the calculation exact. Having, however, the sine, the cosine may be found from it by the property of the right-angled triangle CBF, viz. the cosine CF $= \sqrt{CB^2 - BF^2}$, or $c = \sqrt{1 - s^2}$. There are other methods of constructing tables, but we think it unnecessary to mention them; our sole object being here merely to give a notion of the mode by which such tables are formed.

1049. Prob. II. *To compute the tangents and secants.*

Having, by the foregoing problem, found the sines and cosines, the tangents and secants are easily found from the principles of similar triangles. In the arc AB (*fig.* 395.), where BF is the sine, CF or BK the cosine, AH the tangent, CH the secant, DL the cotangent, and CL the cosecant, the radius being CA or CB or CD; the three similar triangles CFB, CAH, CDL, give the following proportions: —

I. CF : FB :: CA : AH, by which we find that the tangent is a fourth proportional to the cosine, sine, and radius.

II. CF : CB :: CA : CH, by which we find that the secant is a third proportional to the cosine and radius.

III. BF : FC :: CD : DL, by which we find that the cotangent is a fourth proportional to the sine, cosine, and radius.

IV. BF : BC :: CD : CL, by which we find that the cosecant is a third proportional to the sine and radius.

Observation 1. There are therefore three methods of resolving triangles, or the cases of trigonometry; viz. geometrical construction, arithmetical computation, and instrumental operation. The method of carrying out the first and the last does not need explanation: the method is obvious. The second method, from its superior accuracy in practice, is that whereof we propose to treat in this place.

Observation 2. Every triangle has six parts, viz. three sides and three angles. And in all cases of trigonometry, three parts must be given to find the other three. And of the three parts so given, one at least must be a side; because, with the same angles, the sides may be greater or less in any proportion.

Observation 3. All the cases in trigonometry are comprised in three varieties only; viz.

1st. When a side and its opposite angle are given. 2d. When two sides and the contained angle are given. 3d. When the three sides are given.

More than these three varieties there cannot possibly be; and for each of them we shall give a separate theorem.

1050. Theorem I. *When a side and its opposite angle are two of the given parts.*

Then — the sides of the triangle have the same proportion to each other as the sines of their opposite angles have. That is,

As any one side
Is to the sine of its opposite angle,
So is any other side
To the sine of its opposite angle.

For let ABC (*fig.* 397.) be the proposed triangle, having AB the greatest side, and BC the least. Take AD as a radius equal to BC, and let fall the perpendiculars DE, CF, which will evidently be the sines of the angles A and B, to the radius AD or BC. Now the triangles ADE, ACF are equiangular; they therefore have their like sides proportional, namely, AC : CF :: AD or BC : DE, that is, the sine AC is to the sine of its opposite angle B as the side BC is to the sine of its opposite angle A.

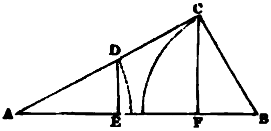


Fig. 397.

Note 1. In practice, when an angle is sought, the proportion is to be begun with a side opposite a given angle; and to find a side, we must begin with the angle opposite the given side.

Note 2. By the above rule, an angle, when found, is ambiguous; that is, it is not certain whether it be acute or obtuse, unless it come out a right angle, or its magnitude be such as to remove the ambiguity; inasmuch as the sine answers to two angles, which are supplements to each other; and hence the geometrical construction forms two triangles with the same parts, as in an example which will follow: and if there be no restriction or limitation included in the question, either result may be adopted. The degrees in a table answering to the sine is the acute angle; but if the angle be obtuse, the degrees must be subtracted from 180 degrees, and the remainder will be the obtuse angle. When a given angle is obtuse, or is one of 90 degrees, no ambiguity can occur, because neither of the other angles can then be obtuse, and the geometrical construction will only form one triangle.

Example 1. In the plane triangle ABC,

Let AB be 345 feet,
BC 232 feet,
$\angle$A 37° 20′:
Required the other parts.

First, to the angles at C and B (*fig.* 398.)

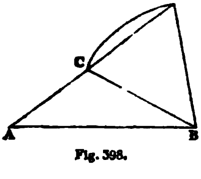


Fig. 398.

As the side BC=232		Log. 2·365488
To sine opp. ∠ A= 37° 20′		9·782796
So side AB =345		2·537819
To sine opp. ∠ C=115° 36′ or 64° 24′	=	9·955127
Add ∠ A= 37 20 37 20		
The sum =152 56 101 44		
Taken from 180 00 180 00		
Leaves ∠ B 27 04 78 16		

It is to be observed here that the second and third logarithms are added (that is, the numbers are multiplied), and from the sum the first logarithm is subtracted (that is, division by the first number), which leaves the remainder 9·955127, which, by the table of sines, is found to be that of the angle 115° 36′, or 64° 24′.

To find the side AC.

As sine ∠ A	= 37° 30′	Log. 9·782796
To opp. side BC	= 232	2·365488
So sine ∠ B	= { 27 04	9·658037
	78 16	9·990829
To opp. side AC	= 174 07	2·240729
Or	374 56	2·573521

Example 2. In the plane triangle ABC,
Let AB=365 yards,
∠ A = 57° 12′
∠ B = 24 45

Herein two angles are given, whose sum is 81° 57′. Therefore 180°−81° 57′= ∠, &c.

As sine ∠ C= 98° 3′		Log. 9·9956993
Is to AB = 365		2·5622929
So sine ∠ B= 24° 45′		9·6218612
To side AC=154 33′		=2·1884548

To find the side BC.

As sine ∠ B= 24° 45′		Log. 9·6210612
Is to AC =154 33		2·1884548
So sin. ∠ A = 57 12		9·9245721
To side BC=309 86		=2·4911657

1051. THEOREM II. *When two sides and their contained angle are given.*

The given angle is first to be subtracted from 180° or two right angles, and the remainder will be the sum of the other two angles. Divide this remainder by 2, which will give the half sum of the said unknown angles; and using the following ratio, we have —

As the sum of the two given sides
Is to their difference,
So is the tangent of half the sum of their opposite angles
To the tangent of half the difference of the same angles.

Now the half sum of any two quantities increased by their half difference gives the greater, and diminished by it gives the less. If, therefore, the half difference of the angles above found be added to their half sum, it will give the greater angle, and subtracting it will leave the lesser angle. All the angles thus become known, and the unknown side is then found by the former theorem.

For let ABC (*fig.* 399.) be the proposed triangle, having the two given sides AC, BC, including the given angle C. With the centre C and radius CA, the less of these two sides, describe a semicircle, meeting the other side BC produced in D, E, and the unknown side AB in A, G. Join AE, CG, and draw DE parallel to AE. Now BE is the sum of the given sides AC, CB, or of EC, CB; and BD is the difference of these given sides. The external angle ACE is equal to the sum of the two internal or given angles CAB, CBA; but the angle ADE at the circumference is equal to half the angle ACE at the centre; wherefore the same angle ADE is equal to half the sum of the given angles CAB, CBA. Also the external angle AGC of the triangle BGC is equal to the sum of the two internal angles GCB, GBC, or the angle GCB is equal to the difference of the two angles AGC, GBC; but the angle CAB is equal to the said angle AGC, these being opposite to the equal sides AC, CG; and the angle DAB at the circumference is equal to half the angle DCG at the centre. Therefore the angle DAB is equal to half the difference of the two given angles CAB, CBA, of which it has been shown that ADE or CDA is the half sum.

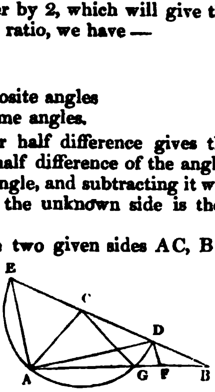


Fig. 399.

Now the angle DAE in a semicircle, is a right angle, or AE is perpendicular to AD; and DF, parallel to AE, is also perpendicular to AD: therefore AE is the tangent of CDA the half sum; and DF, the tangent of DAB, the half difference of the angles to the same radius AD, by the definition of a tangent. But the tangents AE, DF being parallel, it will be as BE : BD :: AE : DF; that is, as the sum of the sides is to the difference of the sides, so is the tangent of half the sum of the opposite angles to the tangent of half their difference.

It is to be observed, that in the third term of the proportion the cotangent of half the given angle may be used instead of the tangent of the half sum of the unknown angles.

Example. In the plane triangle ABC (*fig.* 400.),

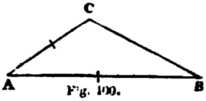


Fig. 400.

Let AB = 345 ft.
AC = 174·07 ft.
∠ A = 37° 20′.

Now, the side AB being	345		From	180° 00′
The side AC	174·07		Take ∠ A	37 20
Their sum is	519·07		Sum of C and B	142 40
Their difference	170·93		Half sum of do.	71 20

As the sum of their sides AB, AC	= 519·07	Log. 2·715226
To difference of sides AB, AC	= 170·93	2·232818
So tang. half sum ∠s C and B	= 71° 20′	10·471298
To tang. half diff. ∠s C and B	= 44 16	9·988890
These added, give ∠ C	= 115 36	
And subtracted, give ∠ B	= 27 4	

By the former theorem: —

As sine ∠ C 115° : 36′, or 64° 24′	Log. 9·955126
To its opposite side AB 345	2·537819
So sine ∠ A 37° 20′	9·782796
To its opposite side BC 232	2·365489

1052. Theorem III. *When the three sides of a triangle are given.*

Let fall a perpendicular from the greatest angle on the opposite side, or base, dividing it into two segments, and the whole triangle into two right-angled triangles, the proportion will be —

As the base or sum of the segments
Is to the sum of the other two sides,
So is the difference of those sides
To the difference of the segments of the base.

Then take half the difference of these segments, and add it to the half sum, or the half base, for the greater segment; and for the lesser segment subtract it.

Thus, in each of the two right-angled triangles there will be known two sides and the angle opposite to one of them, whence, by the first theorem, the other angles will be found.

For the rectangle under the sum and difference of the two sides is equal to the rectangle under the sum and difference of the two segments. Therefore, forming the sides of these rectangles into a proportion, their sums and differences will be found proportional.

Example. In the plane triangle ABC (*fig.* 401.),

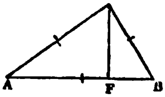


Fig. 401.

Let AB = 345 ft.
AC = 232 ft.
BC = 174·07.

Letting fall the perpendicular CP,
Base BC : AC + BC :: AC − BC : AP − BP;
That is, 345 : 406·07 :: 57·93 : 68·18 = AP − BP;

Its half is	34·09
The half base is	172·50
The sum of these is	206·59 = AP
And their difference	138·41 = BP

Then, in the triangle APC right-angled at P,

As the side AC	= 232	Log. 2·365488
To sine opp. ∠ P	= 90°	10·000000
So is side AP	= 206·59	2·315109
To sine opp. ∠ ACP	= 62° 56′	9.949621
Which subtracted from	= 90 0	
Leaves ∠ A	= 27 04	

Again, in the triangle BPC, right-angled at P,

As the side BC	= 174·07	- Log. 2·240724
To sine opp. ∠ P	= 90° 00′	- 10·000000
So is side BP	= 138·41	- 2·141168
To sine opp. ∠ BCP	= 52° 40′	- 0·990444
Which taken from	90 00	
Leaves the ∠ B	= 37 20	
Also the angle ACP	= 62 56	
Added to the angle BCP	= 52·40	
Gives the whole angle ACB	= 115·36	

So that the three angles are as follow, viz. ∠ A 27° 4′; ∠ B 37° 20′; ∠ C 115° 36.

1053. Theorem IV. *If the triangle be right-angled, any unknown part may be found by the following proportion:* —

As radius
Is to either leg of the triangle,
So is tangent of its adjacent angle
To the other leg;
And so is secant of the same angle
To the hypothenuse.

For AB being the given leg in the right-angled triangle ABC, from the centre A with any assumed radius AD describe an arc DE, and draw DF perpendicular to AB, or parallel to BC. Now, from the definitions, DF is the tangent and AF the secant of the arc DE, or of the angle A, which is measured by that arc to the radius AD. Then, because of the parallels BC, DF, we have AD : AB :: DF : BC, and :: AF : AC, which is the same as the theorem expresses in words.

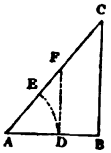


Fig. 402.

Note. Radius is equal to the sine of 90°, or the tangent of 45°, and is expressed by 1 in a table of natural sines, or by 10 in logarithmic sines.

Example 1. In the right-angled triangle ABC,

Let the leg AB = 162
∠ A = 53° 7′ 48″

As radius	= tang. 45°	- Log. 10·000000
To leg AB	= 162 -	- 2·209515
So tang. : ∠ A	= 53° 7′ 48″	- 10·124937
To leg BC	= 216 -	- 2·334452
So secant ∠ A	= 53° 7′ 48″	- 10.221848
To hypothenuse AC	= 270 -	- 2·431363

Note. There is another mode for right-angled triangles, which is as follows: —

ABC being such a triangle, make a leg AB radius; or, in other words, from the centre A and distance AB describe an arc BF. It is evident that the other leg BC will represent the tangent and the hypothenuse AC the secant of the arc BF or of the angle A.

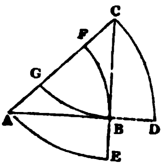


Fig. 403.

In like manner, if BC be taken for radius, the other leg AB represents the tangent, and the hypothenuse AC the secant of the arc BG or angle C.

If the hypothenuse be made radius, then each leg will represent the sine of its opposite angle; namely, the leg AB the sine of the arc AE or angle C, and the leg BC the sine of the arc CD or angle A.

Then the general rule for all such cases is, that the sides of the triangle bear to each other the same proportion as the parts which they represent. This method is called making every side radius.

1054. If two sides of a right-angled triangle are given to find the third side, that may be found by the property of the squares of the sides (Geom. Prop. 32.; viz. That the square of the hypothenuse or longest side is equal to both the squares of the two other sides together). Thus, if the longest side be sought, it is equal to the square root of the sum of the two shorter sides; and to find one of the shorter sides, subtract one square from the other, and extract the square root of the remainder.

1055. The application of the foregoing theorems in the cases of measuring heights and distances will be obvious. It is, however, to be observed, that where we have to find the length of inaccessible lines, we must employ a line or base which can be measured, and, by means of angles, which will be furnished by the use of instruments, calculate the lengths of the other lines.

Sect. V.

CONIC SECTIONS.

1056. The *conic sections*, in geometry, are those lines formed by the intersections of a plane with the surface of a cone, and which assume different forms and acquire different properties, according to the several directions of such plane in respect of the axis of the cone. Their species are five in number.

1057. Definitions.—1. A plane passing through the vertex of a cone meeting the plane of the base or of the base produced is called the *directing plane*. The plane VRX (*fig.* 404.) is the directing plane,

2. The line in which the directing plane meets the plane of the base or the plane of the base produced is called the *directrix*. The line RX is the directrix.
3. If a cone be cut by a plane parallel to the directing plane, the section is called a *conic section*, as AMB or AHI (*fig.* 405.)
4. If the plane of a conic section be cut by another plane at right angles passing along the axis of the cone, the common section of the two planes is called *the line of the axis*.

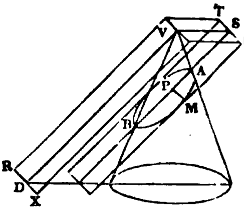


Fig. 404.

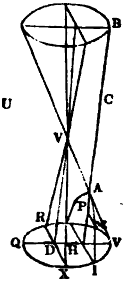


Fig. 405.

5. The point or points in which the line of the axis is cut by the conic surface is or are called the *vertex* or *vertices* of the conic section. Thus the points A and B (*figs.* 404. and 405.) are both vertices, as is the point A or vertex (*fig.* 406.).
6. If the line of the axis be cut in two points by the conic surface, or by the surfaces of the two opposite cones, the portion of the line thus intercepted is called the *primary axis*. The line AB (*figs.* 404. and 405.) and AH (*fig.* 406.) is called the primary axis.
7. If a straight line be drawn in a conic section perpendicular to the line of the axis so as to meet the curve, such straight line is called an *ordinate*, as PM in the above figures.
8. The *abscissa* of an ordinate is that portion of the line of axis contained between the vertex and an ordinate to that line of axis. Thus in figs. 404, 405, and 406. the parts AP, BP of the line of axis are the abscissas AP.

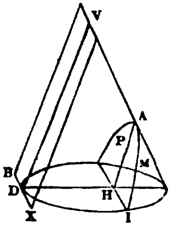


Fig. 406.

9. If the primary axis be bisected, the bisecting point is called the centre of the conic section.
10. If the directrix fall without the base of the cone, the section made by the cutting plane is called an ellipse. Thus, in *fig.* 404., the section AMB is an ellipse. It is evident that, since the plane of section will cut every straight line drawn from the vertex of the cone to any point in the circumference of the base, every straight line drawn within the figure will be limited by the conic surface. Hence the axis, the ordinates, and abscissas will be terminated by the curve.
11. If the directrix fall within the base of the cone, the section made by the cutting plane is called an *hyperbola*. Hence it is evident, that since the directing plane passes alike through both cones, the plane of section will cut each of them, and therefore two sections will be formed. And as every straight line on the surface of the cone and on the same side of the directing plane cannot meet the cutting plane, neither figure can be enclosed.
12. If the directrix touch the curve forming the base of the cone, the section made by the cutting plane is a *parabola*.

OF THE ELLIPSIS.

1058. The primary axis of an ellipsis is called the major axis, as AB (*fig.* 407.); and a straight line DE drawn through its centre perpendicular to it, and terminated at each extremity by the curve, is called the minor axis.

1059. A straight line VQ drawn through the centre and terminated at each extremity by the curve is called a *diameter*. Hence the two axes are also diameters.

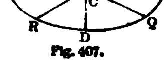


Fig. 407.

1060. The extremities of a diameter which terminate in the curve are called the vertices of that diameter. Thus the points V and Q are the vertices of the diameter VQ.

1061. A straight line drawn from any point of a diameter parallel to a tangent at either extremity of the diameter to meet the curves is called an ordinate to the two abscissas. Thus PM, being parallel to a tangent at V, is an ordinate to the two abscissas VP, PQ.

1062. If a diameter be drawn through the centre parallel to a tangent at the extremity of another diameter, these two diameters are called conjugate diameters. Thus VQ and RS are conjugate diameters.

1063. A third proportional to any diameter and its conjugate is called the *parameter* or *latus rectum.*

1064. The points in the axis where the ordinate is equal to the semi-parameter are called the foci.

1065. THEOREM I. *In the ellipsis the squares of the ordinates of an axis are to each other as the rectangles of their abscissas.*

Let AVB (*fig.* 408.) be a plane passing through the axis of the cone, and AEB another section of the cone perpendicular to the plane of the former; AB the axis of the elliptic section, and PM, HI ordinates perpendicular to it; then it will be

$$PM^2 : HI^2 :: AP \times PB : AH \times HB.$$

For through the ordinates PM, HI draw the circular sections KML, MIN parallel to the base of the cone, having KL, MN for their diameters, to which PM, HI are ordinates as well as to the axis of the ellipse. Now, in the similar triangles APL, AHN,

$$AP : PL :: AH : HN,$$

And in BPK, BHM,

$$BP : PK :: BH : HM.$$

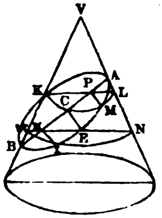


Fig. 408.

Taking the rectangles of the corresponding terms,

$$AP \times BP : PL \times PK :: AH \times BH : HN \times HM.$$

By the property of the circle,

$$PL \times PK = PM^2 \text{ and } HN \times HM = HI^2. \quad \text{Therefore,}$$
$$AP \times BP : PM^2 :: AH \times HB : HI^2, \text{ or}$$
$$PM^2 : HI^2 :: AP \times BP : AH \times HB.$$

Coroll. 1. If C be the centre of the figure, $AP \times PB = CA^2 - CP^2$, and $AH \times HB = CA^2 - CH^2$.

Therefore $PM^2 : HI^2 :: CA^2 - CP^2 : CA^2 - CH^2$. For $AP = CA - CP$, and $PB = CA + CP$: consequently $AP \times PB = (CA - CP)(CA + CP) = CA^2 - CP^2$; and in the same manner it is evident that $AH \times HB = (CA + CH)(CA - CH) = CA^2 - CH^2$.

Coroll. 2. If the point P coincide with the middle point C of the semi-major axis, PM will become equal to CE, and CP will vanish; we shall therefore have

$$PM^2 : HI^2 :: CA^2 - CP^2 : CA^2 - CH^2$$
$$\text{Now } CE^2 : HI^2 :: CA^2 : CA^2 - CH^2, \text{ or } CA^2 \times HI^2 = CE^2(CA^2 - CH^2).$$

1066. THEOREM II. *In every ellipsis the square of the major axis is to the square of the minor axis as the rectangle of the abscissas is to the square of their ordinate.*

Let AB (*fig.* 409.) be the major axis, DE the minor axis, C the centre, PM and HI ordinates to the axis AB; then will

$$CA^2 : CE^2 :: AP \times PB : PM^2.$$

For since by Theor. I., $PM^2 : HI^2 :: AP \times PB : AH \times HB$; and if the point H be in the centre, then AH and HB become each equal to CA, and HI becomes equal to CE; therefore

$$PM^2 : CE^2 :: AP \times PB : CA^2;$$
$$\text{And, alternately, } CA^2 : CE^2 :: AP \times PB :: PM^2.$$

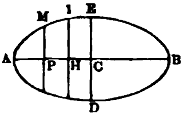


Fig. 409.

Coroll. 1. Hence, if we divide the two first terms of the analogy by AC, it will be $CA : \frac{CE}{CA} :: AP \times PB : PM^2$. But by the definition of parameter, AB : DE :: DE : parameter, or $CA : CE :: 2CE : \text{parameter} = \frac{2CE^2}{CA}$. Therefore $\frac{2CE^2}{CA}$ is the parameter, which let us call P; then

$$AB : P :: AP \times PB : PM^2.$$

Coroll. 2. Hence $CA^2 : CE^2 :: CA^2 - CP^2 : PM^2$. For $CA^2 - CP^2 = (CA - CP)$ $CA + CP) = (AP \times PB)$.

Coroll. 3. Hence, also, $A : P :: CA^2 - CP^2 : PM^2$.

1067. Theorem III. *In every ellipsis, the square of the minor axis is to the square of the major axis as the difference of the squares of half the minor axis and the distance of an ordinate from the centre on the minor axis to the square of that ordinate.*

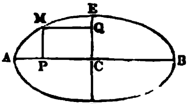


Fig. 410.

Draw MQ (*fig.* 410.) parallel to AB, meeting CE in Q; then will

$$CE^2 : CA^2 :: CE^2 - CQ^2 : QM^2;$$

For by Cor. 2. Theor. II., $CA^2 : CA^2 - CP^2 :: CE^2 : PM^2$;
Therefore, by division, $CA^2 : CP^2 :: CE^2 : CE^2 - PM^2$.

Therefore, since $CQ = PM$ and $CP = QM$; $CA^2 : QM^2 :: CE^2 : CE^2 - CQ^2$.

Coroll. 1. If a circle be described on each axis as a diameter, one being inscribed within the ellipse, and the other circumscribed about it, then an ordinate in the circle will be to the corresponding ordinate in the ellipsis as the axis belonging to this ordinate is to the axis belonging to the other; that is,

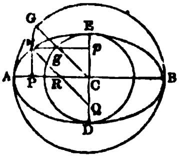


Fig. 411.

$$CA : CE :: PG : PM,$$
$$\text{and } CE : CA :: pg : pM;$$
$$\text{and since } CA^2 : CE^2 :: AP \times PB : PM^2,$$
$$\text{and because } AP \times PB = PG^2;\ CA^2 : CE^2 :: PG^2 : PM^2,$$
$$\text{or } CA : CE :: PG : PM.$$

In the same manner it may be shown that $CE : CA :: pg : pM$, or, alternately, $CA : CE :: pM : pg$; therefore, by equality, $PG : PM :: pM : pg$, or $PG : Cp :: CP : pg$: therefore CgG is a continued straight line.

Coroll. 2. Hence, also, as the ellipsis and circle are made up of the same number of corresponding ordinates, which are all in the same proportion as the two axes, it follows that the area of the whole circle and of the ellipsis, as also of any like parts of them, are in the same ratio, or as the square of the diameter to the rectangle of the two axes; that is, the area of the two circles and of the ellipsis are as the square of each axis and the rectangle of the two; and therefore the ellipsis is a mean proportional between the two circles.

Coroll. 3. Draw MQ parallel to GC, meeting ED in Q; then will $QM = CG = CA$; and let R be the point where QM cuts AB; then, because RMGC is a parallelogram, RM is equal to $CG = CE$; and therefore, since QM is equal to CA, half the major axis and $RM = CE$, half the minor axis QR is the difference of the two semi-axes, and hence we have a method of describing the ellipsis. This is the principle of the trammel, so well known among workmen.

If we conceive it to move in the line DE, and the point R in the line AB, while the point M is carried from A, towards E, B, D, until it return to A, the point M will in its progress describe the curve of an ellipsis.

1068. Theorem IV. *The square of the distance of the foci from the centre of an ellipsis is equal to the difference of the square of the semi-axes.*

Let AB (*fig.* 412.) be the major axis, C the centre, F the focus, and FG the semi-parameter; then will $CE^2 = CA^2 - CF^2$. For draw CE perpendicular to AB, and join FE. By Cor. 2. Th. II., $CA^2 : CE^2 :: CA^2 - CF^2 : FG^2$, and the parameter FG is a third proportional to CA, CE; therefore $CA^2 : CE^2 :: CE^2 : FG^2$, and as in the two analogies the first, second, and fourth terms are identical, the third terms are equal; consequently

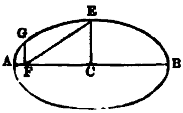


Fig. 412.

$$CE^2 = CA^2 - CF^2.$$

Coroll. 1. Hence $CF^2 = CA^2 - CE^2$.

Coroll. 2. The two semi-axes and the distance of the focus from the centre are the sides of a right-angled triangle CFE, and the distance FE from the focus to the extremity of the minor axis is equal to CA or CB, or to half the major axis.

Coroll. 3. The minor axis CE is a mean proportional between the two segments of the axis on each side of the focus. For $CE^2 = CA^2 - CF^2 = (CA + CF) \times (CA - CF)$.

1069. Theorem V. *In an ellipsis, the sum of the lines drawn from the foci to any point in the curve is equal to the major axis.*

Let the points F, *f* (*fig.* 413.) be the two foci, and M a point in the curve; join FM and *f*M, then will $AB = 2CA = FM + fM$.

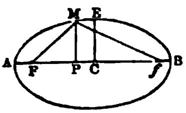


Fig. 413.

By Cor. 2. Th. II., $CA^2 : CE^2 :: CA^2 - CP^2 : PM^2$,
But by Th. IV., $CE^2 = CA^2 - CF^2$;
Therefore $CA^2 : CA^2 - CF^2 :: CA^2 - CP^2 : PM^2$;

And by taking the rectangle of the extremes and means, and dividing the equation by CA^2, the result is—

$$PM^2 = CA^2 - CP^2 - CF^2 + \frac{CF^2 . CP^2}{CA^2}.$$

And because $FP^2 = (CF - CP)^2 = CF^2 - 2CF . CP + CP^2$,
And since $FM^2 = PM^2 + FP^2$.
Therefore $FM^2 = CA^2 - 2CF . CP + \frac{CF^2 . CP^2}{CA^2}$.

Extracting the root from each number, $FM = CA - \frac{CF . CP}{CA}$.

In the same manner it may be shown that $FM = CA + \frac{CF . CP}{CA^2}$; therefore the sum of these is $FM + fM = 2CA$.

Coroll. 1. A line drawn from a focus to a point in the curve is called a radius vector, and the difference between either radius vector and half the major axis is equal to half the difference between the radius vectors. For, since

$$fM = CA - \frac{CF . CP}{CA}; \text{ therefore, by transposition,}$$
$$\frac{CF . CP}{CA} = CA - fM.$$

Coroll. 2. Because $\frac{CF . CP}{CA}$ is a fourth proportional to CA, CF, CP; therefore $CA : CF :: CP : CA - fM$.

Coroll. 3. Hence the difference between the major axis and one of the radius vectors gives the other radius vector. For, since $FM + Mf = 2CA$;

Therefore $FM = 2CA - Mf$.

Coroll. 4. Hence is derived the common method of describing an ellipsis mechanically, by a thread or by points, thus: — Find the foci Ff (*fig.* 414.), and in the axis AB assume any point G; then with the radius AG from the point F as a centre describe two arcs H, H, one on each side of the axis; and with the same radius from the point f describe two other arcs h, h, one on each side of the major axis. Again, with the distance GB from the point f describe two arcs, one on each side of the axis, intersecting the arcs HH in the points HH; and with the same radius from the point f describe two other arcs, one on each side of the axis, intersecting the arcs described at h, h in the point h, h. In this manner we may find as many points as we please; and a sufficient number being found, the curve will be formed by tracing it through all the points so determined.

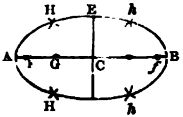


Fig. 414.

1070. THEOREM VI. *The square of half the major axis is to the square of half the minor axis as the difference of the squares of the distances of any two ordinates from the centre to the difference of the squares of the ordinates themselves.*

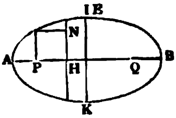


Fig. 415.

Let PM and HI (*fig.* 415.) be ordinates to the major axis AB; draw MN parallel to AB, meeting HI in the point N; then will $PM = HN$, and $MN = PH$, and the property to be demonstrated is thus expressed —

$$CA^2 : CE^2 :: CP^2 - CH^2 : HI^2 - HN^2.$$

Or by producing HI to meet the curve in the point K, and making $CQ = CP$, the property to be proved will be

$$CA^2 : CE^2 :: PH \times HQ : KN.$$

By Cor. 2. Theor. II. $\begin{cases} CA^2 : CE^2 :: CA^2 - CP^2 : PM^2, \\ CA^2 : CE^2 :: CA^2 - CH^2 : HI^2. \end{cases}$

Therefore $CA^2 - CH^2 : CA^2 - CP^2 :: HI^2 : PM^2$ or HN^2;
But, by division, $CA^2 - CH^2 : CP^2 - CH^2 :: HI^2 : HI^2 - HN^2$.
Alternately, $CA^2 - CH^2 : HI^2 :: CP^2 - CH^2 : HI^2 - HN^2$;
And, since we have above, $CA^2 - CH^2 : HI^2 :: CA^2 : CE^2$,
Therefore, by equality, $CA^2 : CE^2 :: CP^2 - CH^2 : HI^2 - HN^2$;
But since $CP^2 - CH^2 = (CP - CH)(CP + CH) = PH \times QH$,
And since $HI^2 - HN^2 = (HI - HN)(HI + HN) = NI \times KN$,
Therefore $CA^2 : CE^2 :: PH \times HQ : NI \times NK$.

Coroll. 1. Hence half the major axis is to half the minor axis, or the major axis is to the minor axis, as the difference of the squares of any two ordinates from the centre is to the rectangle of the two parts of the double ordinate, which is the greatest made of the sum and difference of the two semiordinates. For $KN = HK + HN = HI + HN$, which is the sum of the two ordinates, and $NI = HI - HN$, which is the difference of the two ordinates.

Coroll. 2. Hence, because $CP^2 - CH^2 = (CP - CH)(CP + CH)$, and since $HI^2 - HN^2 = (HI - HN)(HI + HN)$, and because $CP - CH = PH$ and $HI - HN = NI$; therefore $CA^2 : CE^2 :: (CP + CH)PH : (HI + HN)NI$.

1071. Theorem VII. *In the ellipsis, half the major axis is a mean proportional between the distance of the centre and an ordinate, and the distance between the centre and the intersection of a tangent to the vertex of that ordinate.*

To the major axis draw the ordinates PM (*fig.* 416.) and HI, and the minor axis CE. Draw MN perpendicular to HI. Through the two points I, M draw MT, IT, meeting the major axis produced in T; then will $CT : CA :: CA : CP$. For,

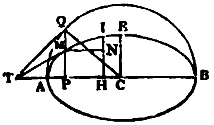


Fig. 416.

By Cor. 1. Theor. VI., $CE^2 : CA^2 :: (IH+HN)IN : (PC+CH)HP$;

By Cor. 2. Th. II., $CE^2 : CA^2 :: PM^2 : CA^2-CP^2$;

Therefore, by equality, $PM^2 \cdot\cdot CA^2-CP^2 :: (IH+HN)IN : (PC+CH)HP$.

By similar triangles, INM, MPT; $IN : NM$ or $PH :: PM : PT$ or $CT-CP$.

Therefore, taking the rectangles of the extremes and means of the two last equations, and throwing out the common factors, they will be converted to the equation

$$PM(CT-CP)(CP+CH)=(CA^2-CP^2)(IH+HN).$$

But when HI and PM coincide, HI and HN will become equal to PM, and CH will become equal to CP; therefore, substituting in the equation 2CP for CP + PH, and 2PM for IH + HN, and throwing out the common factors and the common terms, we have

$$CT \, . \, CP=CA^2$$

$$\text{or } CT : CA :: CA : CP.$$

Coroll. 1. Since CT is always a third proportional to CP and CA, if the points P, A, B remain fixed, the point T will be the same; and therefore the tangents which are drawn from the point M, which is the intersection of PQ, and the curve, will meet the curve in the point T in every ellipsis described on the same axis AB.

Coroll. 2. When the outer ellipsis AQB, by enlarging, becomes a circle, draw QT perpendicular to CQ, and joining TM, then TM will be a tangent to the ellipsis at MM.

Coroll. 3. Hence, if it were required to draw a tangent from a given point T in the prolongation of the major axis to the ellipsis AEB, it will be found thus: — On AB describe the semicircle AQB. Draw a tangent TQ to the circle, and draw the ordinate PQ intersecting the curve AEB of the ellipsis in the point M; join TM; then TM is the tangent required. This method of drawing a tangent is extremely useful in practice.

1072. Theorem VIII. *Four perpendiculars to the major axis intercepted by it and a tangent will be proportionals when the first and last have one of their extremities in the vertices, the second in the point of contact, and the third in the centre.*

Let the four perpendiculars be AD, PM, CE, BF, of which AD and BF have their extremities in the vertices A and B, the second in the point of contact M, and the third in the centre C; then will

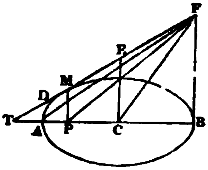


Fig. 417.

$$AD : PM :: CE : BF.$$

For, by Theor. VII., $TC : AC :: AC : CP$;

By division, $TC-AC : CA-CP :: TC : AC$ or CB;

That is, $TA : AP :: TC : CB$.

By composition, $TA : TA+AP :: TC : TC+CB$:

Therefore $TA : TP :: TC : TB$.

But by the similar triangles TAD, TPM, TCE, and TBF, the sides TA, TP, TC, and TB are proportionals to the four perpendiculars AD, PM, CE, and BF; therefore

$$AD : PM :: CE : BF.$$

Coroll. 1. If AM and CF be joined, the triangles TAM and TCF will be similar. For by similar triangles, the sides TD, TM, TE, TF are in the same proportion as the sides TA, TP, TC, TB.

Therefore $TD : TM :: TE : TF$;

Alternately, $TD : TE :: TM : TF$: but TAD is similar to TCE;

Hence $TD : TE :: TA : TC$;

Therefore, by equality, $TA : TM :: TC : TF$.

Coroll. 2. The triangles APM and CBF are similar;

For $TA : TP :: TC : TB$.

By division, $TP : TP-TA :: TB : TB-TC$;

That is, $TP : AP :: TB : CB$.

Alternately, $TP : TB :: AP : CB$: but TPM is similar to TBF;

Consequently, $TP : TB :: PM : BF$:

Therefore, by equality, $AP : PM :: CB : BF$.

Coroll. 3. If AF be drawn cutting PM in I, then will PI be equal to the half of PM.

For, since $AP : PM :: CB : BF$, and, by the similar triangles API, ABF,
$AP : PI :: AB : BF$;
Therefore $PM : PI :: CB : AB$.

But CB is the half of AB; therefore, also, PI is the half of PM.

1073. THEOREM IX. *If two lines be drawn from the foci of an ellipse to any point in the curve, these two lines will make equal angles with a tangent passing through that point.*

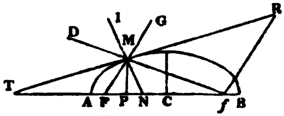


Fig. 418.

Let TM (*fig.* 418.) be a tangent touching the curve at the point M, and let F, f be the two foci; join FM, fM, then will the angle FMT be equal to the angle fMR. For draw the ordinate PM, and draw fR parallel to FM, then will the triangles TFM and TfR be similar; and by Cor. Theor. VII.,

$CA : CP :: CT : CA$;
By Cor. 2. Theor. V., $CA : CP :: CF : CA - FM$;
Therefore, by equality, $CT : CF :: CA : CA - FM$.
By division and composition, $CT - CF : CT + CF :: FM : 2CA - FM$;
That is, $TF : Tf :: FM : fM$.
By the similar triangles TFM, TfR; $TF : Tf :: FM : fR$.

It therefore appears that fM is equal to fR, therefore the angle fMR is equal to the angle fRM: but because FM and fR are parallel lines, the angle FMT is equal to the angle fRM; therefore the angle FMT is equal to the angle fMR.

Coroll. 1. Hence a line drawn perpendicular to a tangent through the point of contact will bisect the angle FMf, or the opposite angle DMG. For let MN be perpendicular to the tangent TR. Then, because the angle NMT and NMR are right angles, they are equal to one another; and since the angles FMT and fMR are also equal to one another, the remaining angles NMF and NMf are equal to one another. Again, because the opposite angles FMN and IMG are equal to one another, and the opposite angle fMN and IMD are equal to one another; therefore the straight line MI, which is the line MN produced, will also bisect the angle DMG.

Coroll. 2. The tangent will bisect the angle formed by one of the radius vectors, and the prolongation of the other. For prolong FM to G. Then, because the angles RMN and RMI are right angles, they are equal to one another; and because the angles NMf and IMD are equal to one another, the remaining angles RMG and RMf are equal to one another.

Scholium. Hence we have an easy method of drawing a tangent to any given point M in the curve, or of drawing a perpendicular through a given point in the curve, which is the usual mode of drawing the joints for masonic arches. Thus, in order to draw the line IM perpendicular to the curve: produce FM to G, and fM to D, and draw MI bisecting the angle DMG; then IM will be perpendicular to the tangent TR, and consequently to the curve.

As in optics the angle of incidence is always found equal to the angle of reflection, it appears that the foundation of that law follows from this theorem; for rays of light issuing from one focus, and meeting the curve in any point, will be reflected into lines drawn from these points to the other focus: thus the ray fM is reflected into MF: and this is the reason why the points Ff are called *foci*, or burning points. In like manner, a sound in one focus is reflected in the other focus.

1074. THEOREM X. *Every parallelogram which has its sides parallel to two conjugate diameters and circumscribes an ellipsis is equal to the rectangle of the two axes.*

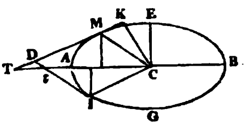


Fig. 419.

Let CM and CI (*fig.* 419.) be two semi conjugate diameters. Complete the parallelogram CIDM. Produce CA and MD to meet in T, and let AT meet DI in t. Draw IH and PM ordinates to the axis, and draw half the minor axis CE. Produce DM to K, and draw CK perpendicular to DK: then will the parallelogram CIDM be equal to the rectangle, whose sides are CA and CE; or four times the rectangle CIDM will be equal to the rectangle made of the two axes AB and GE.

By Cor. Theor. VII., $\left\{\begin{array}{l} CA : CT :: CP : CA, \\ Ct : CA :: CA : CH; \end{array}\right.$
Therefore $Ct : CT :: CP : CH$.
By the similar triangles CtI, TCM, $Ct : CT :: CI : TM$;
By equality, therefore, $CI : TM :: CP : CH$.
By the similar triangles CIH, TMP, $CI : TM :: CH : PT$;
Therefore, by equality, $CH : PT :: CP : CH$.
Consequently $CP \times PT = CH^2$.
But by Theor. VII., $CP \times CT = CA^2$;
Therefore, since $CT = CP + PT$, $CP^2 + CP.PT = CA^2$,

And, by transposition, $CP.PT = CA^2 - CP^2$;
Hence, by equality, $CH^2 = CA^2 - CP^2$,
Or, by transposition, $CP^2 = CA^2 - CH^2$.
But by Cor. 2. Theor. I., $CA^2 \times HI^2 = CE^2(CA^2 - CH^2)$,
And substituting CP^2 for its equal $CA^2 - CH^2$, we have $\Big\}$ $CA^2 \times HI^2 = CE^2 \times CP^2$;
Therefore $CA : CP :: CE : HI$.
But again, by Theor. VII., $CA : CP :: CT : CA$;
By equality, therefore, $CE : HI :: CT : CA$.
But by the similar triangles HIC, KCT, $HI : CI :: CK : CT$;
Therefore $CE : CI :: CK : CA$:
Consequently $CE \times CA = CI \times CK$.

The ellipsis is of so frequent occurrence in architectural works, that an acquaintance with all the properties of the curve, and the modes of describing it, is of great importance to the architect. Excepting the circle, which may be called an ellipsis in which the two foci coincide, it is the most generally employed curve in architecture.

1075. Problem I. *To describe an ellipsis.*

Let two pins at E and F (*fig.* 420.) be fixed in a plane within a string whose ends are made fast at C. If the point C be drawn equally tight while it is moved forward in the plane till it returns to the place from which it commenced, it will describe an ellipsis.

1076. Prob. II. *The two diameters* AB *and* ED *of an ellipse being given in position and magnitude, to describe the curve through points.*

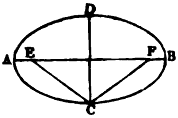


Fig. 420.

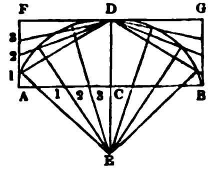


Fig. 421.

Let the two diameters cut each other at C (*fig.* 421.). Draw AF and BG parallel to ED. Divide AC and AF each into the same number of equal parts, and draw lines, as in the figure, through the points of division; viz. those from the line AF to the point D, and the lines through AC to the point E; then through the points of intersection of the corresponding lines draw the curve AD, and in the same manner find the curve BD; then ADB will be the semi-ellipsis.

It is evident that the same method also extends to a circle by making CD equal to CA; (*fig.* 422.); and it appears that the two lines forming any point of the curve to be drawn will make a right angle with each other. For these lines terminate at the extremities of the diameter ED, and the point of concourse being in the curve, the angle made by them must be a right angle; that is, the angle EAD, or E*h*D, or E*i*D, or E*k*D, is a right angle: and from this property we have the following method of drawing the segment of a circle through points found in the curve.

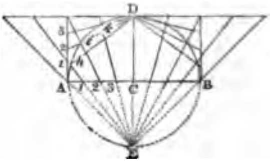


Fig. 422.

Thus, let AB be the chord, and CD be the versed sine of an arc of a circle, to describe the arc. Through D draw HI (*fig.* 423.) parallel to AB; join AD and DB; draw AH perpendicular to AD, and BI perpendicular to BD; divide AC and HD each into the same number of equal parts, and join the corresponding points; divide AF into the same number of equal parts, and through the points of division draw lines to D, and through the corresponding points where these lines meet the former draw a curve AD. In the same manner the other half BD may be drawn.

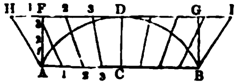


Fig. 423.

1077. Prob. III. *A diameter* KH *of an ellipsis being given, and an ordinate* DL, *to find the limits of the other conjugate diameter.*

Bisect KH in I (*fig.* 424.), through I draw EA parallel to DL, and draw DC and KB perpendicular to EA; from the point L with the distance K describe an arc cutting EA at F; join LF, and produce LF to C; make IE and IA each equal to LG; then will EA be a diameter conjugate to KH.

1078. Prob. IV. *A diameter* KH *and an ordinate* DL *of an ellipsis being given, to describe the curve.* (See *fig.* 424.)

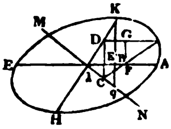


Fig. 424.

Find the limits E and A of the other conjugate diameter by the preceding construction. Produce KB to *q*, and make K*q* equal to IA or IE, and through the centre I of the curve and the point *q*, draw the straight line MN. Then, suppose the straight line KB*q* to be an inflexible rod, having the point B marked upon it. Move the rod round, so that the point *q* on the rod may be in the line MN, while the point B is in the line EA; then, at any instant of the motion, the place of the point K on the plane whereon the figure is to be drawn may be marked; the points thus found will be in the curve. Instead of a rod, a slip of paper may be used, and in some cases a rod with adjustible points to slide in a cross groove, and a sliding head for a pencil is convenient; and such an instrument is called a *trammel.*

When the diameters KH and EA (*fig.* 425.) are at right angles to each other, the straight line Kq coincides with the diameter KH, and consequently the line MN, on which the point q of the inflexible line Kq moves, will also fall upon the diameter KH. Therefore in this case nothing more is required to find the limits of the other diameter, than to take the half diameters IK, KH of the given diameters, and from the extremity L with that distance describe an arc cutting the unlimited diameter in the point F; then drawing LF, and producing it to q, and making IE and IA each equal to qL, EA will be the other diameter; and since the two diameters are at right angles to each other, they are the two axes given in position and magnitude, and thus the curve may be described as before.

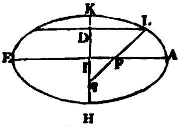


Fig. 425.

A method of describing the curve from any two conjugate diameters is occasionally of considerable use, and particularly so in perspective. For, in every representation of a circle in perspective, a diameter and a double ordinate may be determined by making one of the diameters of the original circle perpendicular to the plane of the picture and the other parallel to it; and then the representation of the diameter of the original circle, which is perpendicular to the intersecting line, will be a diameter of the ellipsis, which is the representation of that circle; and the representation of the diameter of the circle which is parallel to the intersecting line will become a double ordinate to the diameter of the ellipsis which is the perspective representation of the circle.

1079. Prob. V. *Through two given points* A *and* B *to describe an ellipsis, the centre* C *being given in position and the greater axis being given in magnitude only.*

About the centre C (*fig.* 426.) with a radius equal to half the greater axis describe a circle HEDG; join AC and BC; draw AD perpendicular to AC, and BE perpendicular to BC, cutting the circumference in the points D and E; draw also BF parallel to AC, and find BF, which is a fourth proportional to AD, AC, and BE; through the point F and the centre C draw FG to cut the circle in H and G, and GH is the major axis of the ellipsis. By drawing an ordinate Bq, the curve may be described by the preceding problem, having the axis GH and the ordinate Bq.

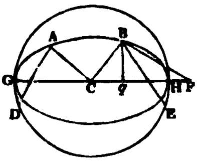


Fig. 426.

1080. Prob. VI. *Through a given point in the major axis of a given ellipsis to describe another similar ellipsis which shall have the same centre and its major axis on the same straight line as that of the given ellipsis.*

Let ACBD (*fig.* 427.) be the given ellipsis, having AB for its major axis and CD for its minor axis, which are both given in position and magnitude. It is required to draw a similar ellipsis through the point G in the major axis AG. Draw BK perpendicular and CK parallel to AB, and join KE. Again, draw GL perpendicular to AB cutting EK at L, and draw LH parallel to AB cutting CD in H. On the axis CD make EI equal to EH, and on the axis AB make EF equal to EG. Then, having the major axis AB, and the minor axis FG, the ellipsis FIGH may be described, and when drawn, it will be similar to the given ellipsis ADBC.

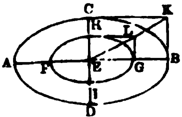


Fig. 427.

1081. Prob. VII. *Through any given point p, within the curve of a given ellipsis to describe another ellipsis which shall be similar and concentric to the given one.*

Let C (*fig.* 428.) be its centre. Draw the straight line CpP, cutting the curve of the given ellipsis in P. In such curve take any other number of points Q, R, S, &c., and join QC, RC, SC, &c.; join PQ and draw pq parallel thereto cutting qC at q: join PR and draw pr parallel to PR, cutting RC at r; join PS and draw ps parallel to PS cutting SC in s. The whole being completed, and the curve p, s, t, u drawn through the points p, q, r, s, &c., the figure will be similar and concentric to the given ellipse P, S, T, U; or when the points at the extremities for one half of the curve have been drawn, the other half may be found by producing the diameter to the opposite side, and making the part produced equal to the other part.

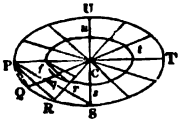


Fig. 428.

1082. Prob. VIII. *About a given rectangle* ABCD *to describe an ellipsis which shall have its major and minor axes respectively parallel to the sides of the rectangle and its centre in the points of intersection of the two diagonals.*

Bisect the sides AD and AB (*fig.* 429.) of the rectangle respectively at L and O;

through L draw GH parallel to AB cutting the opposite side BC of the rectangle in M, and through the point O draw KI parallel to AD or BC cutting the opposite side DC in N. In NK or NK produced, make NQ equal to NC, and join CQ; draw QR parallel to GH cutting CB or CB produced in R; make EH and EG each equal to QC, as also EI and EK each equal to PC; then will GH be the major axis and KI the minor axis of the ellipsis required.

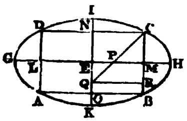


Fig. 429.

The demonstration of this method, in which the line QK has nothing to do with the construction, is as follows: —

By the similar triangles CPM and COR, we have $CP : CM :: CQ : CR$.

But because MP is equal to $MC = EN$, and since CR is equal to $RQ = EM$,

And, by construction, since PC is equal to EI or EK, and QC is equal to EG or EH,

$EI : EN :: EH : EM$, or, alternately, $EI : EH :: EN : EM$.

But EN is equal to MC, and EM equal to NC;

Whence $EI : EH :: MC : CN$.

But since the wholes are as the halves, we shall have $KI : GH :: BC : CD$.

This problem is useful in its application to architecture about domes and pendentives, as well as in the construction of spheroidal ceilings and other details.

OF THE HYPERBOLA.

1083. The direction of a plane cutting a cone, which produces the form called the hyperbola, has been already described; its most useful properties will form the subject of the following theorems, which we shall preface with a few definitions: —

1. The primary axis of an hyperbola is called the *transverse axis.*
2. A straight line drawn through the centre of an hyperbola and terminated at each extremity by the opposite curves is called a *diameter.*
3. The extremities of a diameter terminated by the two opposite curves are called the *vertices of that diameter.*
4. A straight line drawn from any point of a diameter to meet the curve parallel to a tangent at the extremity of that diameter is called *an ordinate* to the two abscissas.
5. A straight line which is bisected at right angles by the transverse axis in its centre, and which is a fourth proportional to the mean of the two abscissas, their ordinate, and the transverse axis, is called the *conjugate axis.*
6. A straight line which is a third proportional to the transverse and conjugate axis is called the *latus rectum* or *parameter.*
7. The two points in the transverse axis cut by ordinates which are equal to the semi-parameter are called the *foci.*

1084. Theorem I. *In the hyperbola the squares of the ordinates of the transverse axis are to each other as the rectangular of their abscissas.*

Let QVN (*fig.* 430.) be a section of the cone passing along the axis VD, the line of section of the directing plane, HB the line of axis of the cutting plane, the directing and cutting plane being perpendicular to the plane QVN. Let the cone be cut by two planes perpendicular to the axis passing through the two points P, H, meeting the plane of section in the lines PM, HI, which are ordinates to the circles and to the figure of the section, of the same time.

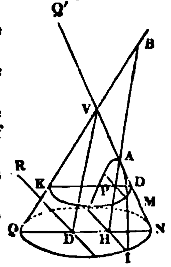


Fig. 430.

By the similar triangles APL and AHN, $AP : PL :: AH : HN$;

And by the similar triangles BPK and BHQ, $BP : PK :: BH : HQ$.

Therefore, taking the rectangles of the corresponding terms, $AP \times BP : PL \times PK :: AH \times BH : HN \times HQ$.

But in the circle, $PL \times PK = PM^2$, and $HN \times HQ = HI^2$;

Therefore $AP \times BP : PM^2 :: AH \times BH : HI^2$,

Or, alternately, $PM^2 : HI^2 :: AP : PB : AH : BH$.

1085. Theorem II. *In the hyperbola, as the square of the transverse axis is to the square of the conjugate axis, so is the rectangle of the abscissas to the square of their ordinate.*

Let AB (*fig.* 431.) be a transverse axis, GE the conjugate axis, C being the centre of the opposite curves; also let HI and PM be ordinates as before; then will

$$AB^2 : GE^2 :: PA \times PB : PM^2,$$

Or $CA^2 : CE^2 :: PA \times PB : PM^2$.

By Theor. I., $PA \times PB : HA \times HB :: PM^2 : HI^2$;

Alternately, $PA \times PB : PM^2 :: HA \times HB :: HI^2$.

But $HA \times HB : HI^2 :: AB^2 : GE^2$;

Therefore $AB^2 : GE^2 :: PA \times PB : PM^2$.

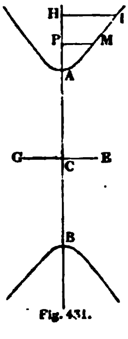


Fig. 431.

Coroll. Hence $AB^2 : GE^2 :: CP^2 - CA^2 : PM^2$ (*fig.* 432.). For let the cutting plane of the opposite hyperbola intersect two circles parallel to the base in HI and PM, and let the cone be cut by another plane parallel to the base, passing through the centre C of the transverse axis, and let mn be the diameter of the circle made by the plane QVN.

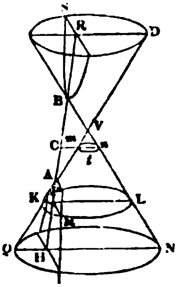


Fig. 432.

Then ACm, APK are similar, and $AC : Cm :: AP : PK$.
And as BCn, BPL are similar, $BC : Cn :: BP : PL$.

Therefore, taking the rectangles of the corresponding terms,

$$BC \times AC : Cn \times Cm :: BP \times AP : PL \times PK.$$

But $BC = AC$; $Cm \times Cn = Ct^2$; and $PL \times PK = PM^2$.
Therefore $AC^2 : Ct^2 :: AP \times BP : PM^2$.

Though Ct is not in the same plane, it is what is usually called the semi-conjugate axis, and it agrees with what has been demonstrated in the first part of this proposition.

1086. THEOREM III. *In the hyperbola, the square of the semi-conjugate axis is to the square of the semi-transverse axis as the sum of the squares of the semi-conjugate axis and of the ordinate parallel to it is to the square of the abscissas.*

Let AB (*fig.* 433.) be the transverse axis, GE the conjugate, C the centre of the figure, and PM an ordinate, then will

$$GE^2 : AB^2 :: CE^2 + PM^2 : CP^2.$$

For, by Theor. II., $CE^2 : CA^2 :: PM^2 : CP^2 - CA^2$,
And, by composition, $CE^2 : CA^2 :: CE^2 + PM^2 : CP^2$.

This demonstration may be also applied to what are called conjugate hyperbolas.

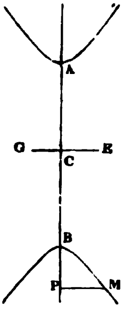


Fig. 433.

1087. THEOREM IV. *In the hyperbola, the square of the distance of the focus from the centre is equal to the sum of the squares of the semi-axes.*

Let AB (*fig.* 434.) be the transverse axis, CE the semi-conjugate. In AB, produced within the curve each way, let F be one focus; and f the other, and let FG be the semi-parameter then $CF^2 = CA^2 + CE^2$.

For, by Theor. I., $CA^2 : CE^2 :: FA \times FB : FG^2$;
But, by property of parameter, $CA^2 : CE^2 :: CE^2 : FG^2$.
Therefore $CE^2 = AF \times FB = CF - CA$;
And, by transposition, $CF^2 = CA^2 + CE^2$.

Coroll. 1. The two semi-axes, and the distance of the focus from the centre, are the sides of a right-angled triangle CEA, of which the distance AE is the distance of the focus from the centre.

Coroll. 2. The conjugate axis CE is a mean proportional between FA and FB, or between fB and fA, for $CE^2 = CF^2 - CA = (CF + CA) \times (CF - CA) = BF \times AF$.

1088. THEOREM V. *The difference of the radius vectors is equal to the transverse axis.*

That is, $fM - FM = AB = 2CA = 2CB$.
For $CA^2 : CE^2 :: CP^2 - CA^2 : PM^2$;
And $CE^2 = CF^2 - CA^2$.
Therefore $CA^2 : CF^2 - CA^2 :: CP^2 - CA^2 : PM^2$.

And by taking the rectangle of the extremes and means, and dividing by CA^2,

$$PM^2 = \frac{CF^2 \times CP^2}{CA^2} - CF^2 - CP^2 + CA^2;$$

But $FP^2 = (CP - CF)^2 = CP^2 = 2CP \times CF + CF^2$,
And $FM^2 = PM^2 + FP^2$.

Therefore $FM^2 = \frac{CF^2 \times CP^2}{CA^2} - 2CP \times CF + CA^2$.

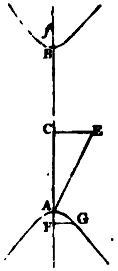


Fig. 434.

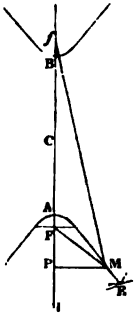


Fig. 435.

Now each side of this equation is a complete square.

Therefore, extracting the root of each number, $FM = \frac{\times CP}{CA} - CA$.

In the same manner we find $fM = \frac{CF \times CP}{CA} + CA$;

And, subtracting the upper equation from the lower, $fM - FM = 2CA$.

Coroll. 1. Hence is derived the common method of describing the hyperbolic curve mechanically. Thus: — In the transverse axis AB produced (*fig.* 435.), take the foci F, f, and any point I in the straight line AB so produced. Then, with the radii AI, BI, and the centre F, *f*, describe arcs intersecting each other; call the points of intersection E, then E will be a point in the curve; with the same distances another point on the other side of the axis may be found. In like manner, by taking any other points I, we may find two more points, one on each side of the axis, and thus continue till a sufficient number of points be found to describe the curve by hand. By the same process, we may also describe the opposite hyperbolas.

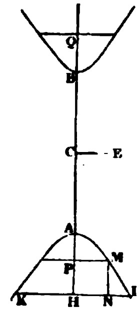


Fig. 436.

Coroll. 2. Because $\frac{CF \times CP}{CA}$ is a fourth proportional, CA, CF, CP $CA : CF :: CP : CA + FM$.

1089. Theorem VI. *As the square of the semi-transverse axis is to the square of the semi-conjugate, so is the difference of the squares of any two abscissas to the difference of the squares of their ordinates.*

By Theor. II., $\begin{cases} CA^2 : CE^2 :: CP^2 - CA^2 : PM^2 \text{ (fig. 436.)}, \\ CA^2 : CE^2 :: CH^2 - CA^3 : HI^2. \end{cases}$

Therefore, by equality, $CH^2 - CA^2 : CP^2 - CA^2 :: HI^2 : PM^2$ or HN^2;

And, by division, $CH^2 - CA^2 : CH^2 - CP^2 :: HI^2 : HI^2 - HN^2$;

Alternately, $CH^2 - CA^2 : HI^2 :: CH^2 - CP^2 : HI^2 - HN^2$.

But $CH^2 - CA^2 : HI^2 :: CA^2 : CE^2$

Therefore $CA^2 : CE^2 :: CH^2 - CP^2 :: HI^2 - HN^2$.

Coroll. 1. If IH be produced to K, and CQ be made equal to CP, then will $CH^2 - CP^2 = (CH + CP)(CH - CP) = (CP + CH)PH$; and $HI^2 - HN^2 = (HI + HN)(HI - HN) = (HI + HN)NI$. Therefore the analogy resulting becomes

$$CA^2 : CE^2 :: (CP + CH)PH : (HI + HN)NI.$$

So that the square of the transverse axis is to the square of the conjugate, or the square of the semi-transverse is to the square of the semi-conjugate, as the rectangle of the sum and difference of the two ordinates from the centre is to the rectangle of the sum and difference of these ordinates.

1090. Theorem VII. *If a tangent and an ordinate be drawn from any point in an hyperbola to meet the transverse axis, the semi-transverse axis will be a mean proportional between the distances of the two intersections from the centre.*

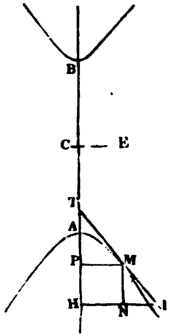


Fig. 437.

For (*fig.* 437.) $CE^2 : CA^2 :: (IH + HN)IN :: (PC + CH)HP$;

And by Theor. I., $CE^2 : CA^2 :: PM^2 : CP^2 - CA^2$;

By equality, $PM^2 : CP^2 - CA^2 :: (IH + HN) IN : (PC + CH)HP$;

And by similar triangles INM, MPT, $IN : NM$ or $PH :: PM : PT$ or $CP - CT$.

Therefore, taking the rectangles of the extremes and means of the two last equations, and neglecting the common factors, it will be $PM(CP - CT)(CP + CH) = (CP^2 - CA^2)(IH + HN)$; but when IH and PM coincide, IH and HN each become equal to PM, and CH equal to CP: therefore in the equation substitute 2CP for CP + CH, and 2PM for IH + HN, and neglecting the common factors and common terms, the result is $CT.CP = CA^2$, or $CT : CA :: CA : CP$.

Coroll. Since CT is always a third proportional to CP, CA; suppose the points P and A to remain constant, the point T will also remain constant; therefore all the tangents will meet in the point T which are drawn from the extremity of the ordinate M of every hyperbola described on the same axis AB.

1091. Theorem VIII. *Four perpendiculars to the transverse axis intercepted by it and a tangent, will be proportionals when the first and last have one of their extremities in each vertex, the second in the point of contact, and the third in the centre.*

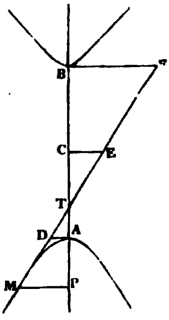


Fig. 438.

Let the four perpendiculars be AD, PM, CE, BF (*fig.* 438.), whereof AD and BF have their extremities in the vertices A and B, and the second in the point of contact M of the tangent and the curve, and the third in the centre C.

Then will $AD : PM :: CE : BF$.

For, by Theor. VII., $CT : CA :: CA : CP$,

And, by division, $CA - CT : CP - CA :: CT : CA$ or CB;

That is, $AT : AP :: CT : CB$;

By composition, $AT : AT + AP :: CT : CT + CB$.

Therefore $AT : TP :: CT : BT$.

But by the similar triangles TAD, TPM, TCE, and TBF, the sides AT, PT, CT, and BT are proportional to the four perpendiculars AD, PM, CE, BF.

Therefore $AP : PM :: CE : BF$.

1092. **THEOREM IX.** *The two radius vectors meeting the curve in the same point will make equal angles with a tangent passing through that point.* (*Fig.* 439.)

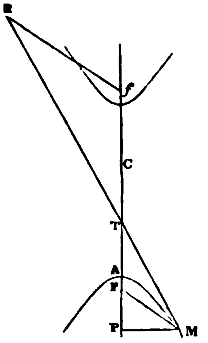


Fig. 439.

For, by Theor. VII., $CA : CP :: CT : CA$;
By Cor. 2. Theor. V., $CA : CP :: CF : CA + FM$;
By equality, $CT : CF :: CA : CA + FM$;
By division and composition, $CF - CT : CF + CT :: FM : 2CA + FM$;
That is, $FT : fT :: FM : fR$;

And by the similar triangles TFM, TfR, $FT : fT :: FM : fR$. Therefore fR is equal to fM; consequently the angle fRM is equal to the angle fMR: and because fR is parallel to fM, the angle FMT is equal to the angle fRM; therefore the angle FMT is equal to the angle fRM.

1093. **PROBLEM I.** *To describe an hyperbola by means of the end of a ruler moveable on a pin* F (*fig* 440.) *fixed in a plane, with one end of a string fixed to a point* E *in the same plane, and the other extremity of the string fastened to the other end* C *of the ruler, the point* C *of the ruler being moved towards* G *in that plane.*

While the ruler is moving, a point D being made to slide along the edge of the ruler, kept close to the string so as to keep each of the parts CD, DE of the string taught, the point D will describe the curve of an hyperbola.

If the end of the ruler at F (*fig.* 441.) be made moveable about the point E, and the string be fixed in F and to the end C of the ruler, as before, another curve may be described in the same manner, which is called the *opposite hyperbola:* the points E and F, about which the ruler is made to revolve, are the foci.

There are many occasions in which the use of this conic section occurs in architectural details. For instance, the profiles of many of the Grecian mouldings are hyperbolic; and in conical roofs the forms are by intersections such that the student should be well acquainted with the methods of describing it.

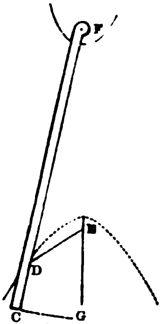


Fig. 440.

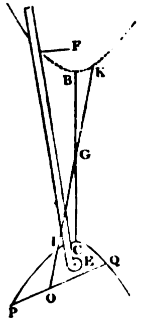


Fig. 441.

1094. **PROB. II.** *Given the diameter* AB, *the abscissa* BC, *and the double ordinate* DE *in position and magnitude, to describe the hyperbola.* (*Fig.* 442.)

Through B draw FG parallel to DE, and draw DF and EG parallel to AB.

Divide DF and DC each into the same number of equal parts, and from the points of division in BF draw lines to B, also from the points of division in DC draw straight lines to A; then through the points of intersection found by the lines drawn through the corresponding points draw the curve DB. In like manner the curve EB may be drawn so that DBE will form the curve on each side of the diameter AB. If the point A be considered as the vertex, the opposite hyperbola HAI may be described in the same manner, and thus the two curves formed by cutting the opposite cones by the same plane will be found. By the theorists, the hyperbola has been considered a proper figure of equilibrium for an arch whose office is to support a load which is greatest at the middle of the arch, and diminishes towards the abutments. This, however, is matter of consideration for another part of this work.

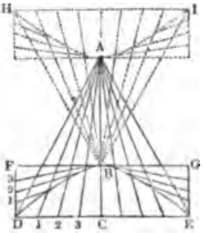


Fig. 442.

OF THE PARABOLA.

1095. **DEFINITIONS.**—1. The parameter of the axis of a parabola is a third proportional to the abscissa and its ordinate.

2. The focus is that point in the axis where the ordinate is equal to the semi-parameter.
3. The diameter is a line within the curve terminated thereby, and is parallel to the axis.
4. An ordinate to any diameter is a line contained by the curve and that diameter parallel to a tangent at the extremity of the diameter.

1096. **Theorem I.** *In the parabola, the abscissas are proportional to the squares of their ordinates.*

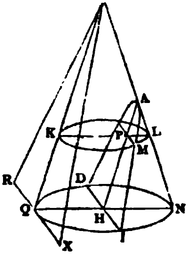


Fig. 443.

Let QVN (*fig.* 443.) be a section of the cone passing along the axis, and let the directrix RX pass through the point Q perpendicular to QN, and let the parabolic section be ADI meeting the base QIND of the cone in the line DI, and the diameter QN in the point H; also let KML be a section of the cone parallel to the base QIN intersecting the plane VQN in the line KL, and the section ADI in PM. Let P be the point of concourse of the three planes QVN, KML, AHI, and let H be the point of concourse of the three planes QVN, KML, AHI; then, because the planes VRX and ADI are parallel, and the plane AQN is perpendicular to the plane ARX, the plane ADI is also perpendicular to the plane AQN. Again, because the plane QIN is perpendicular to the plane QVI, and the plane KML is parallel to the plane QIN, the plane KML is perpendicular to the plane QVN: therefore the common sections PM and HI are perpendicular to the plane AQN; and because the plane KML is parallel to the plane QIN; and these two planes are intersected by the plane QVN, their common sections KL and QN are parallel. Also, since PM and HI are each perpendicular to the plane QVN, and since KL is the common section of the planes QVN, KML, and QN in the common section of the planes QVN, QIN; therefore PM and HI are perpendicular respectively to KI and QN.

Consequently $AP : AH :: PM^2 : HI^2$.
For, by the similar triangles APL, AHN, $AP : AH :: PL : HN$,
Or $AP : AH :: KP \times PL : KP \times HN$.
But, by the circle KML, $KP \times PL = PM^2$,
And, by the circle QIN, $QH \times HN = HI^2$. But $QH = KP$;
Therefore $KP \times HN = HI^2$.
Therefore, by substitution. $AP : AH :: PM^2 : HI^2$.

Coroll. By the definition of the parameter, which we shall call P,

$$AP : PM :: PM : P = \frac{PM^2}{PA},$$

And $P \times AP = PM^2$, or $P \times AH = HI^2$.
Therefore $P : PM :: PM : AP$, or $P : HI :: HI : AH$.

1097. **Theorem II.** *As the parameter of the axis is to the sum of any two ordinates, so is the difference of these ordinates to the difference of their abscissas.*

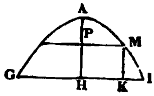


Fig. 444.

That is, $P : HI + PM :: HI - PM : AH - AP$.

For since by Cor. Theor. I. $\left\{ \begin{array}{l} P = \frac{PM^2}{AP}, \\ P = \frac{HI^2}{AH}; \end{array} \right.$

Multiplying the first of these equations by AP and the second by AH,

they become $\left\{ \begin{array}{l} P \times AP = PM^2, \\ P \times AH = HI^2. \end{array} \right.$

Subtract the corresponding numbers of the first equation, and $P(AH - AP) = HI^2 - PM^2$. But the difference of two squares is equal to a rectangle under the sum and difference of their sides.

And $HI^2 - PM^2 = (HI + PM)(HI - PM)$.
Therefore $P(AH - AP) = (HI + PM)(HI - PM)$.
Consequently $P : HI + PM :: HI - PM : AH - AP$;

Or, by drawing KM parallel to AH, we have $GK = PM + HI$, and $KI = HI - PM$; and since $PH = AH - AP$; $P : GK :: KI : PH$, or KM.

Coroll. Hence, because $P \times KM = GK \times KI$;
And since $HI^2 = P \times AH$;
Therefore, by multiplication, $KM \times HI^2 = GK \times KI \times AH$, or
$AH : KM :: HI^2 : GK \times KI$.

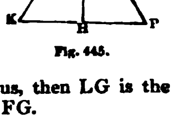


Fig. 445.

So that any diameter MK is as the rectangle of the segments GK, KI of the double ordinate GI. From this a simple method has been used of finding points in the curve, so as to describe it.

1098. **Theorem III.** *The distance between the vertex of the curve and the focus is equal to one fourth of the parameter.*

Let LG (*fig.* 445.) be a double ordinate passing through the focus, then LG is the parameter. For by the definition of parameter $AF : FG :: FG : P = 2FG$.

Therefore $2AF = FG = \frac{1}{2}LG$;
Consequently $AF = \frac{1}{4}LG$.

1099. **THEOREM IV.** *The radius vector is equal to the sum of the distances between the focus and the vertex, and between the ordinate and the vertex.* (*Fig.* 446.)

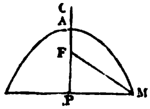


Fig. 446.

That is, $FM = AP + AF.$
For $FP = AP - AF;$
Therefore $FP^2 = AP^2 - 2AP \times AF + AF^2.$
But, by Cor. Theor. II., $PM^2 = P \times AP = 4AF \times AP.$
Therefore, by addition, $FP^2 + PM^2 = AP^2 + 2AF \times AP + AF^2.$
But by the right-angled tringles, $FP^2 + PM^2 = FM^2;$
And therefore $FM^2 = AP^2 + 2AF \times AP + AF^2.$
Hence, extracting the roots, $FM = AP + AF = 2AF + FP;$
Or by making $AG = AF$, $FM = GP.$

Coroll. 1. If through the point G (*fig.* 447.) the line GQ be drawn perpendicular to the axis, it is called the directrix of the parabola.

By the property shown in this theorem, it appears that if any line QM be drawn parallel to the axis, and if FM be joined, the straight line FM is equal to QM; for QM is equal to GP.

Coroll. 2. Hence, also, the curve is easily described by points. Take AG equal to AF, (*fig.* 447.), and draw a number of lines M, M perpendicular to the axis AP; then with the distances GP, GP, &c. as radii, and from F as a centre, describe arcs on each side of AP, cutting the lines MM, MM, &c. at MM, &c.; then through all the points M, M, M, &c. draw a curve, which will be a parabola.

1100. **THEOREM V.** *If a tangent be drawn from the vertex of an ordinate to meet the axis produced, the subtangent* PT (*fig.* 448.) *will be equal to twice the distance of the ordinate from the vertex.*

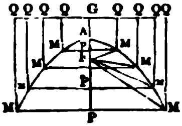


Fig. 447.

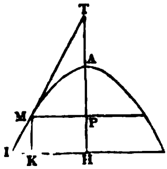


Fig. 448.

If MT be a tangent at M, the extremity of the ordinate PM; then the sub-tangent PT is equal to twice AP. For draw MK parallel to AH,

Then, by Theor. II., $KM : KI :: GK :: P;$
And as MKI, TPM are similar, $KM : KI :: PT : PM.$
Therefore, by equality, $P : PM :: GK : PT;$
And by Cor. Theor. I., $P : PM :: PM : AP.$
Therefore, by equality, $AP : PT :: PM : GK.$

But when the ordinates HI and PM coincide, MT will become a tangent, and GK will become equal to twice PM.

Therefore $AP : PT :: PM : 2PM$, or
$PT = 2AP.$

From this property is obtained an easy and accurate method of drawing a tangent to any point of the curve of a parabola. Thus, let it be required to draw a tangent to any point M in the curve. Produce PA to T (*fig.* 449.), and draw MP perpendicular to PT, meeting AP in the point P. Make AP equal to AP, and join MT, which will be the tangent required.

1101. **THEOREM VI.** *The radius vector is equal to the distance between the focus and the intersection of a tangent at the vertex of an ordinate and the axis produced.*

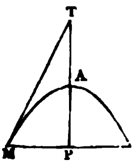


Fig. 449.

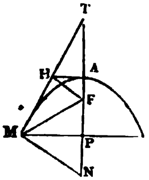


Fig. 450.

Produce PA to T (*fig.* 450.), and let MT be a tangent at M; then will $FT = FM$.

For $FT = AF + AT;$
But, by last theorem, $AP = AT;$
Therefore $FT = AF + AP.$
But, by Theorem III., $FM = AF + AP;$
Therefore, by equality, $FM = FT.$

Coroll. 1. If MN be drawn perpendicular to MT to meet the axis in N, then will $FN = FM = FT$. For draw FH perpendicular to MT, and it also bisects MT, because $FM = FT$; and since HF and MN are parallel, and MT is bisected in H, the line TN will also be bisected in F. It therefore follows that $FN = FM = FT$.

Coroll. 2. The *subnormal* PN is a constant quantity, and it is equal to half the parameter, or to 2AF. For since TMN is a right angle,

Therefore $2AP$ or $TP : PM :: PM : PN.$
But, by the definition of parameter, $AP : PM :: PM : P;$
Therefore $PN = \frac{1}{2}P.$

Coroll. 3. The tangent of the vertex AH is a mean proportional between AF and AP. For since FHT is a right angle, therefore AH is a mean proportional between AF and AT; and since AT = AP, AH is a mean proportional between AF and AP. Also FH is a mean proportional between FA and FT, or between FA and FM.

Coroll. 4. The tangent makes equal angles with FM and the axis AP, as well as with FC and CI.

1102. Theorem VII. *A line parallel to the axis, intercepted by a double ordinate and a tangent at the vertex of that ordinate, will be divided by the curve in the same ratio as the line itself divides the double ordinate.*

Let QM (*fig.* 451.) be the double ordinate, MT the tangent, AP the axis, GK the intercepted line divided by the curve in the point I; then will GI : IK :: MK : KQ.

For by similar triangles MKG, MPT; MK : KG :: PM : PT, or 2AP;

By the definition of parameter, P : PM :: PM : 2AP;

Therefore, by equality, P : MK :: PM : KG;

And again, by equality, PM : MK :: 2AP : KG;

And by division, MK : KQ :: GI : IK.

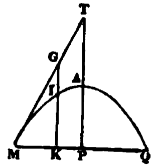


Fig. 451.

1103. Problem I. *To describe a parabola.*

If a thread, equal in length to the leg BC (*fig.* 452.) of a right angle or square, be fixed to the end C, and the other end of the thread be fixed to a point F in a plane, then if the square be moved in that plane so that the leg AB may slide along the straight line GH, and the point D be always kept close to the edge BC of the square, and the two parts FD and DC of the string kept stretched, the point D will describe a curve on the plane, which will be a parabola.

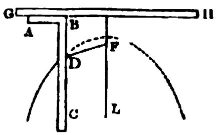


Fig. 452.

1104. Prob. II. *Given the double ordinate* DE *and the abscissa* BC *in position and magnitude, to describe a parabola.*

Through B (*figs.* 453, 454.) draw FG parallel to DE and DF, and EG parallel to CD. Divide DC and DF each into the same number of equal parts. From the points of division in DE draw lines to B. Through the points of division in DC draw lines parallel to BC, and through the points of intersection of the corresponding lines draw a curve, and complete the other half in the same manner; then will DBE be the complete curve of the parabola. The less BC is in proportion to CD, the nearer the curve will approach to the arc of a circle, as in fig. 422.; and hence we may describe the curve for diminishing the shaft of a column, or draw a flat segment of a circle.

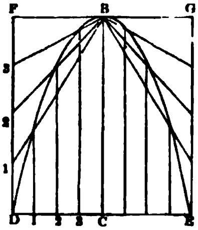


Fig. 453.

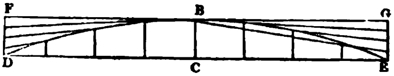


Fig. 454.

1105. Prob. III. *The same parts being given, to describe the parabola by the intersection of straight lines.*

Produce CB to F (*fig.* 455.), and make BF equal to BC. Join FD and FE. Divide DF and FE in the same proportion, or into the same number of equal parts. Let the divisions be numbered from D to F, and from F to E, and join every two corresponding points by a straight line; then the intersection of all the straight lines will form the parabola required.

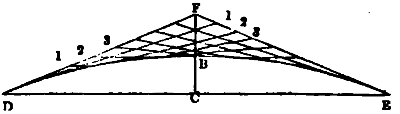


Fig. 455.

1106. Prob. IV. *To draw a straight line from a given point in the curve of a parabola, which shall be a tangent to the curve at that point.*

Let DC (*fig.* 456.) be the double ordinate, CB the abscissa to the parabolic curve DBC, and let it be required to draw a tangent from the point *e* in the curve. Draw *ef* parallel to DC, cutting BC in *f*: produce CB to *g*, and make B*g* equal to B*f*, and join *ge*, then will *ge* be the tangent required. In the same manner DH will be found to be a tangent at D. If *e*K be drawn perpendicular to the tangent *ge*, then will *e*K be also perpendicular to the curve, and in the proper direction for a joint in the masonry of a parabolic arch.

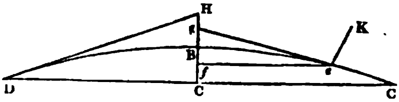


Fig. 456.

1107. The uses of the parabolic curve in architecture are many. The theorists say that it is the curve of equilibrium for an arch which has to sustain a load uniformly diffused over its length, and that therefore it should be included in the depth of lintels and flat arches; and that it is nearly the best form for suspension and other bridges, and for roofs. It is also considered the best form for beams of equal strength. It may be here also remarked, that it is the curve described by a projectile, and that it is the form in which a jet of water is delivered from an orifice made in the side of a reservoir. So is it the best curve for the reflection of light to be thrown to a distance. In construction it occurs in the intersection of conic surfaces by planes parallel to the side of the cone, and is a form of great beauty for the profiles of mouldings, in which manner it was much used in Grecian buildings.

GENERAL METHOD OF DETERMINING THE SPECIES AND OF DESCRIBING CONIC SECTIONS.

1108. In a conic section, let there be given the abscissa AB (*fig.* 457.), an ordinate BC, and a tangent CD to the curve at the extremity of the ordinate to determine the species of the conic section, and to describe the figure.

Draw AD parallel to BC, and join AC (Nos. 1. and 2.). Bisect AC in E, and produce DE and AB, so as to meet in F when DE is not parallel to AB; then in the case where DE will meet AB or AB produced in F, the point F will be the centre of an ellipsis or hyperbola. In this case produce AF to G, and make FG equal to FA; then if the ordinate BC and the centre be upon the same side of the apex A, the curve to which the given parts belong is an ellipsis; but if they be on different sides of it, the curve is an hyperbola. When the line DE (No. 3.) is parallel to AB, the figure is a parabola.

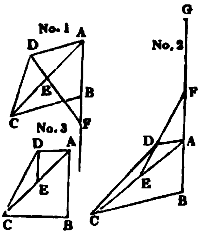


Fig. 457.

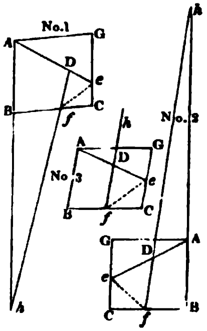


Fig. 458.

1109. In a conic section, the abscissa AB (*fig.* 458.), an ordinate BC, and a point D in the curve being given, to determine the species of the curve, and thence to describe it.

Draw CG parallel to AB (Nos. 1. and 2.), and AG parallel to BC. Join AD, and produce it to meet CG in *e*. Divide the ordinate CB in *f* in the same proportion as CG is divided, then will C*f* : *f*B :: C*e* : *e*G. Join D*f*, and produce it or *f*D to meet AB or BA in *h*; then if the points D and *h* fall upon opposite sides of the ordinate BC, the curve is an ellipsis; but if D and *h* fall upon the same side of the ordinate BC, the curve will be an hyperbola. If D*f* (No. 3.) be parallel to AB, the curve will be a parabola. In the case of the ellipsis and hyperbola, A*h* is a diameter; and therefore we have a diameter and ordinate to describe the curve.

Sect. VI.

DESCRIPTIVE GEOMETRY.

1110. The term Descriptive Geometry, first used by Monge and other French geometers to express that part of the science of geometry which consists in the application of geometrical rules to the representation of the figures and the various relations of the forms of bodies, according to certain conventional methods, differs from common perspective by the design or representation being so made that the exact distance between the different points of the body represented can always be found; and thus the mathematical relations arising from its form and position may be deduced from the representation. Among the English writers on practical architecture, it has usually received the name of *projection*, from the circumstance of the different points and lines of the body being projected on the plane of representation; for, in descriptive geometry, points in space are represented by their orthographical projection on two planes at right angles to each other, called the *planes of projection*, one of which planes is usually supposed to be horizontal, in which case the other is vertical, the projections being called horizontal or vertical, according as they are on one or other of these planes.

1111. In this system, a point in space is represented by drawing a perpendicular from it to each of the planes of projection; the point whereon the perpendicular falls is the projection of the proposed point. Then, as points in space are the boundaries of lines, so their projections similarly form lines, by whose means their projection is obtained; and by the projections of points lying in curves of any description, the projections of those curves are obtained.

1112. For obvious reasons, surfaces cannot be similarly represented; but if we suppose the surface to be represented, covered by a system of lines, according to some determinate law, then these lines projected on each of the two planes will, by their boundaries, enable us to project the surface in a rigorous and satisfactory manner.

1113. There are, however, some surfaces which may be more simply represented; for a plane is completely defined by the straight lines in which it intersects the two planes of projection, which lines are called the *traces* of the plane. So a sphere is completely defined by the two projections of its centre and the great circle which limits the projections of its points. So also a cylinder is defined by its intersection (or trace) with one of the planes of projection and by the two projections of one of its ends; and a cone by its intersection with one of the planes of projection and the two projections of its summit.

1114. Monge, before mentioned, Hachette, Vallée, and Leroi, are the most systematic writers on this subject, whose immediate application to architecture, and to the mechanical arts, and most especially to engineering, is very extensive; in consequence, indeed, of which it is considered of so much importance in France, as to form one of the principal departments of study in the Polytechnic School of Paris. A sufficient general idea of it for the architectural student may be obtained in a small work of Le Croix, entitled, *Complément des Elemens de Geometrie.* In the following pages, and occasionally in other parts of this work, we shall detail all those points of it which are connected more immediately with our subject, inasmuch as we do not think it necessary to involve the reader in a mass of scientific matter connected therewith, which we are certain he would never find necessary in the practice of the art whereon we are engaged.

1115. In order to comprehend the method of tracing geometrically the projections of all sorts of objects, we must observe,—I. That the visible faces only of solids are to be expressed. II. That the surfaces which enclose solids are of two sorts, rectilinear and curved. These, however, may be divided into three classes,—1st. Those included by plane surfaces, as prisms, pyramids, and, generally, similar sorts of figures used in building. 2d. Those included by surfaces whereof some are plane and others with a simple curvature, as cylinders, cones, or parts of them, and the voussoirs of arches. 3d. Solids enclosed by one or several surfaces of double flexure, as the sphere, spheroids, and the voussoirs of arches on circular planes.

1116. *First class, or solids with plane surfaces.*—The plane surfaces by which these solids are bounded form at their junction edges or *arrisses*, which may be represented by right lines.

1117. And it is useful to observe in respect of solids that there are three sorts of angles formed by them. *First*, those arising from the meeting of the lines which bound the faces of a solid. *Second*, those which result from the concurrence of several faces whose edges unite and form the summit of an angle: thus a solid angle is composed of as many plane angles as there are planes uniting at the point, recollecting however that their number must be at least three. *Third*, the angles of the planes, which is that formed by two of the faces of a solid. A cube enclosed by six square equal planes comprises twelve rectilineal edges or arrisses and eight solid angles.

1118. Pyramids are solids standing on any polygonal bases, their planes or faces being triangular and meeting in a point at the top, where they form a solid angle.

1119. Prisms, like pyramids, may be placed on all sorts of polygonal bases, but they rise on every side of the base in parallelograms instead of triangles, thus having throughout similar form and thickness.

1120. Though, strictly speaking, pyramids and prisms are polyhedrons, the latter term is only applied to those solids whose faces forming polygons may each be considered as the base of a separate pyramid.

1121. In all solids with plane surfaces the arrisses terminate in solid angles formed by several of these surfaces, which unite with one another; whence, in order to find the projection of the right lines which represent those arrisses, all that we require to know is the position of the solid angles where they meet; and as a solid angle is generally composed of several plane angles, a single solid angle will determine the extremity of all the arrisses by which it is formed.

1122. *Second class: solids terminated by plane and curved surfaces.*— Some of these, as cones for instance, exhibit merely a point and two surfaces, one curved and the other flat. The meeting of these surfaces forms a circular or elliptical arris common to both. The projection of an entire cone requires several points for the curvature which forms its base, but a single point only is necessary to determine its summit. This solid may be considered as a pyramid with an elliptic or circular base; and to facilitate its projection a polygon is inscribed in the ellipsis or circle, which serves as its base.

1123. If the cone is truncated or cut off, polygons may in like manner be inscribed in the curves which produce the sections.

1124. Cylinders may be considered as prisms whose bases are formed by circles, ellipses, or other curves, and their projections may be obtained in a similar manner: that is, by inscribing polygons in the curves which form their bases.

1125. *Third class: solids whose surfaces have a double curvature.*—A solid of this sort may be enclosed in a single surface, as a sphere or spheroid.

1126. As these bodies present neither angles nor lines, they can only be represented by the apparent curve which seems to bound their superficies. This curve may be determined by tangents parallel to a line drawn from the centre of the solid perpendicularly to the plane of projection.

1127. If these solids are truncated or cut by planes, we must, after having traced the curves which represent them entire, inscribe polygons in each curve produced by the sections, in order to proceed as directed for cones and cylinders.

1128. To obtain a clear notion of the combination of several pieces, as, for instance, of a vault, we must imagine the bodies themselves annihilated, and that nothing remains but the arrisses or edges which form the extremes of the surfaces of the voussoirs. The whole assemblage of material lines which would result from this consideration being considered transparent would project upon a plane perpendicular to the rays of light, *traces* defining all these edges that we have supposed material, some foreshortened, and others of the same size. These will form the outlines of the vault, whence follow the subjoined remarks.

I. That in order, on a plane, to obtain the projection of a right line representing the arris of any solid body, we must on such plane let fall verticals from each of its extremities.

II. That if the arris be parallel to the plane of the drawing, the line which represents its projection is the same size as the original.

III. That if it be oblique, its representation will be shorter than the original line.

IV. That perpendiculars by means of which the projection is made being parallel to each other, the line projected cannot be longer than the line it represents.

V. That in order to represent an arris or edge perpendicular to the plane of projection, a mere point marks it because it coincides in the length with the perpendiculars of projection.

VI. That the measure of the obliquity of an arris or edge will be found by verticals let fall from its extremities.

1129. In conducting all the operations relative to projections, they are referable to two planes, whereof one is horizontal and the other vertical.

PROJECTION OF RIGHT LINES.

1130. The projection of a line AB (*fig.* 459.) perpendicular to a horizontal plane is expressed on such plane by a point K, and by the lines *ab*, *a'b'*, equal to the original on vertical planes, whatever their direction.

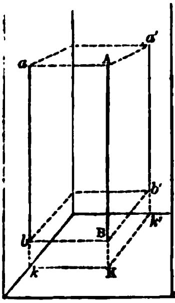


Fig. 459.

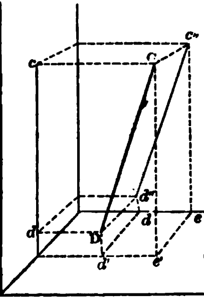


Fig. 460.

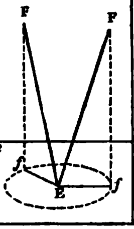


Fig. 461.

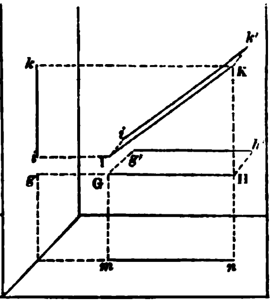


Fig. 462.

1131. An inclined line CD (*fig.* 460.) is represented on an horizontal or a vertical plane by *cd*, *c'd'*, shorter than the line itself, except on a vertical plane, parallel to its projection, and on the horizontal plane *c''d''*, where it is equal to the original CD.

1132. An inclined line EF (*fig.* 461.) moveable on its extremity E, may, by preserving the same inclination in respect of the plane on which it lies, have its projection successively in all the radii of the circle E*f*, determined by the perpendicular let fall from the point F.

1133. Two lines GH, IK (*fig.* 462.), whereof one is parallel to an horizontal plane and the other inclined, may have the same projection *m*, *n*, upon such plane. Upon a vertical plane perpendicular to *mn*, the projection of the line GH will be a point *g*; and that of the inclined line IK, the vertical *ik*, which measures the inclination of that line. Lastly, on a vertical plane parallel to *mn*, the projection *i'k'* and *g'h'* will be parallel and equal to the original lines.

PROJECTION OF SURFACES.

1134. What has been said in respect of right lines projected on vertical and horizontal planes may be applied to plane surfaces; thus, from the surface ABCD (*fig.* 463.), parallel to an horizontal plane, results the projection *abcd* of the same size and form. An inclined surface EFGH may have, though longer, the same projection as the level one ABCD, if the lines of projection AE, BF, DH, CG are in the same direction.

1135. The level surface ABCD would have for projection on vertical planes the right lines *ab*, *b'c'*, because that surface is in the same plane as the lines of projection.

1136. The inclined surface EFGH will give on vertical planes the foreshortened figure *hgef* of that surface; and upon the other the simple line *fq*, which shows the profile of its inclination, because this plane is parallel to the side of the inclined surface.

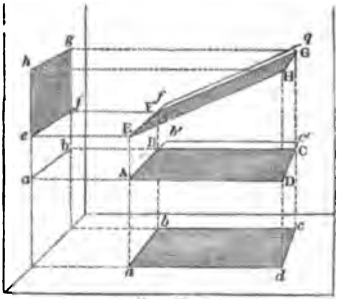


Fig. 463.

PROJECTION OF CURVED LINES.

1137. Curve lines not having their points in the same direction occupy a space which brings them under the laws of those of surfaces. The projection of a curve on a plane parallel to the surface in which it lies (*fig.* 464.) is similar to the curve.

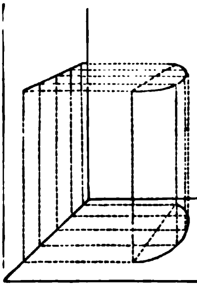


Fig. 464.

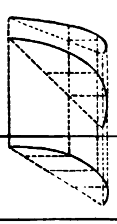


Fig. 465.

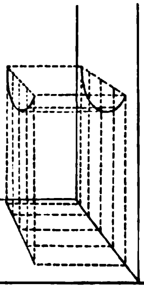


Fig. 466.

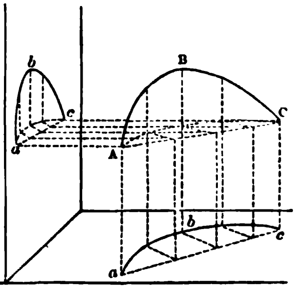


Fig. 467.

1138. If the plane of projection be not parallel, a foreshortened curve is the result, on account of its obliquity with the surface (*fig.* 465.).

1139. If the curve be perpendicular to the plane of projection, we shall have a line representing the profile of the surface in which it is comprised; that is to say, a right line if the surface lie in the same plane (*fig.* 466.), and a curved line if the surface be curved (*fig.* 467.).

1140. In order to describe the projection of the curve line ABC (*fig.* 467.), if the surface in which it lies is curved, and it is not perpendicular to the plane of projection, a polygon must be inscribed in the curve, and from each of the angles of such polygon a perpendicular must be let fall, and parallels made to the chords which subtend the arcs. But it is to be observed, that this line having a double flexure, we must further inscribe a polygon in the curvature which forms the plane *abc* of the surface wherein the curved line lies.

1141. The combination and developement of all the parts which compose the curved surfaces of vaults being susceptible of representation upon vertical and horizontal planes by right or curve lines terminating their surfaces, if what has been above stated be thoroughly understood, it will not be difficult to trace their projections for practical purposes, whatever their situation and direction in vaults or other surfaces.

PROJECTION OF SOLIDS.

1142. The projections of a cube ABCDEFGH placed parallel to two planes, one horizontal and the other vertical, are squares whose sides represent faces perpendicular to these planes (*fig.* 468.), which are represented by corresponding small letters.

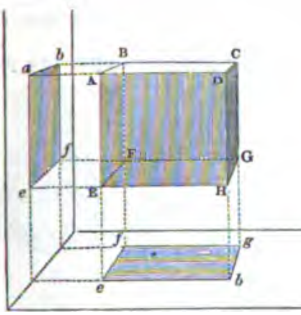


Fig. 468.

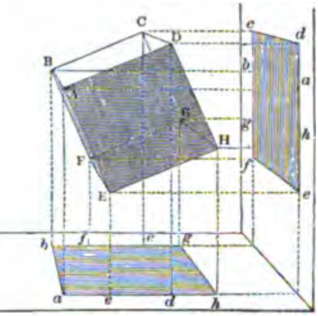


Fig. 469.

1143. If we suppose the cube to move on an axis, so that two of its opposite faces remain perpendicular to the planes (*fig.* 469.), its projection on each will be a rectangle, whose length will vary in proportion to the difference between the side and the diagonal of the square. The motion of the opposite arrisses will, on the contrary, produce a rectangle whose width will be constant in all the dimensions contained of the image of the perfect square to the exact period when the two arrisses unite in a single right line.

1144. A cylinder (*fig.* 470.) stands perpendicularly on an horizontal plane, and on such plane its projection ADBC is shown, being thereon represented by a circle, and upon a vertical plane by the rectangle *gcdh*.

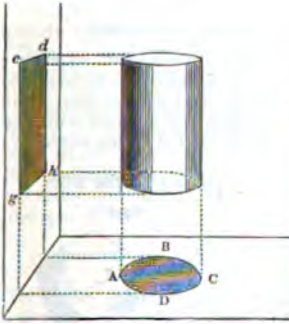


Fig. 470.

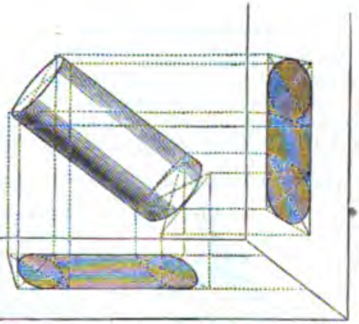


Fig. 471.

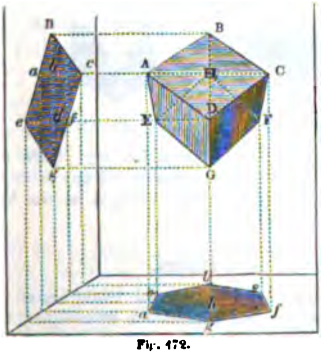


Fig. 472.

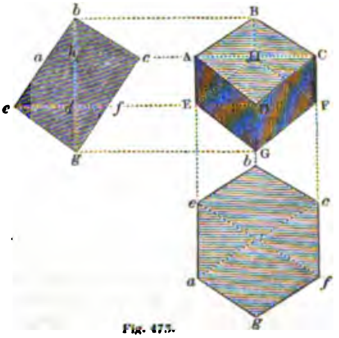


Fig. 473.

1145. The projection of an inclined cylinder (*fig.* 471.) is shown on a vertical and horizontal plane.

1146. In *fig.* 472. we have the representation of a cube doubly inclined, so that the diagonal from the angle B to the angle G is upright. The projection produced by this position upon an horizontal plane is a regular hexagon *acbefg*, and upon a vertical plane the rectangle B*egc* whose diagonal B*g* is upright; but as the effect of perspective changes the effect of the cube and its projections, it is represented geometrically in *fig.* 473.

1147. In *figures* 474. and 475. a pyramid and cone are represented with their projectins on horizontal and vertical planes.

1148. *Fig.* 476. represents a ball or sphere with its projections upon two planes, one vertical and the other horizontal, wherein is to be remarked the perfection of this solid, seeing that its projection on a plane is always a circle whenever the plane is parallel to the circular base formed by the contact of the tangents.

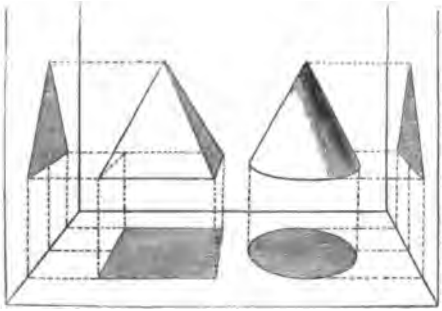


Fig. 474. Fig. 475.

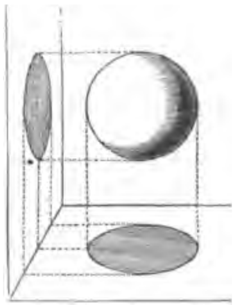


Fig. 476.

DEVELOPEMENT OF SOLIDS WHOSE SURFACES ARE PLANE.

1149. We have already observed that solids are only distinguished by their apparent faces, and that in those which have plane surfaces, their faces unite so as to form solid angles. We have also observed that at least three plane angles are necessary to form a solid angle; whence it is manifest that the most simple of all the solids is a pyramid with a triangular base, which is formed by four triangles, whereof three are united in the angles at its apex. (*Fig.* 477.)

1150. The developement of this solid is obtained by placing on the sides of the base, the three triangles whose faces are inclined (*fig.* 478.); by which we obtain a figure composed of four triangles. To cut this out in paper, for instance, or any other flexible material, after bending it on the lines *ab*, *bc*, *ac*, which form the triangle at the base, the three triangles are turned up so as to unite in the summit.

Fig. 477.

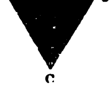


Fig. 479.

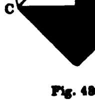
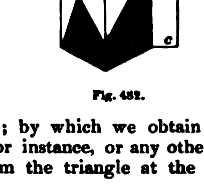


Fig. 481.



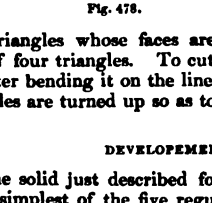


Fig. 478.

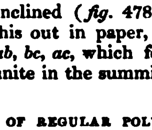


Fig. 480.

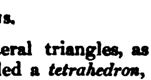


Fig. 482.

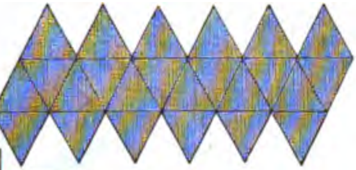
DEVELOPEMENT OF REGULAR POLYHEDRONS.

1151. The solid just described formed of four equal equilateral triangles, as we have seen, is the simplest of the five regular polyhedrons, and is called a *tetrahedron*, from its being composed of four similar faces. The others are —

The *hexahedron*, or cube whose faces are six in number;
The *octahedron*, whose faces are eight equilateral triangles;
The *dodecahedron*, whose faces are twelve regular pentagons;
The *icosahedron*, consisting of twenty equilateral triangles.

These five regular polyhedrons are represented by the *figures* 477. 479, 480, 481, and 482., and their developement by the *figures* 478. 483, 484, 485, and 486.

Fig. 486.



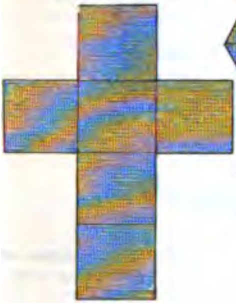


Fig. 483.

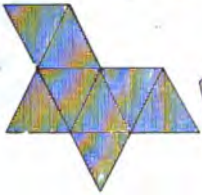


Fig. 484.

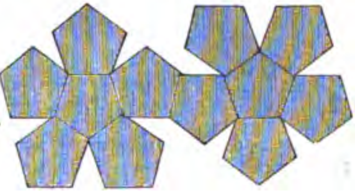


Fig. 485.

1152. The surfaces of these developements are so arranged as to be capable of being united by moving them on the lines by which they are joined.

1153. It is here proper to remark, that the equilateral triangle, the square, and the pentagon, are the only figures which will form regular polyhedrons whose angles and sides are equal; but by cutting in a regular method the solid angles of these polyhedrons, others regularly symmetrical may be formed whose sides will be formed of two similar figures. Thus, by cutting in a regular way the angles of a tetrahedron, we obtain a polyhedron of eight faces, composed of four hexagons and four equilateral triangles. Similarly operating on the cube, we shall have six octagons, connected by eight equilateral triangles, forming a polyhedron of fourteen faces.

1154. The same operation being performed on the octahedron also gives a figure of fourteen faces, whereof eight are octagons and six are squares.

1155. The dodecahedron so cut produces twelve pentagons united by twenty hexagons, and having thirty-two sides. This last, from some points of view, so approaches the figure of the sphere, that, at a little distance, it looks almost spherical.

DEVELOPEMENT OF PYRAMIDS AND PRISMS.

1156. The other solids whose surfaces are plane, whereof mention has already been made, are pyramids and prisms, partaking of the tetrahedron and cube; of the former, inasmuch as their sides above the base are formed by triangles which approach each other so as together to form the solid angle which is the summit of the pyramid; of the latter, because their faces, which rise above the base, are formed by rectangles or parallelograms which preserve the same distance from each other, but differ, from their rising on a polygonal base and being undetermined as to height.

1157. This species may be regular or irregular, they may have their axes perpendicular or inclined, they may be truncated or cut in a direction either parallel or inclined to their bases.

1158. The developement of a pyramid or right prism, whose base and height are given, is not attended with difficulty. The operation is by raising on each side of the base a triangle equal in height to the inclined face, as in the pyramidal figures 487. and 488., and a rectangle equal to the perpendicular height if it be a prism.

DEVELOPEMENT OF AN OBLIQUE PYRAMID.

1159. If the pyramid be oblique, as in *fig.* 489., wherein the length of the sides of each triangle can only be represented by foreshortening them in a vertical or horizontal projection, a third operation is necessary, and that is founded on a principle common to all projections; viz. *that the length of an inclined line projected or foreshortened on a plane, depends upon the difference of the perpendicular elongation of its extremities from the plane,* *whence in all cases a rectangular triangle, whose vertical and horizontal projections give two sides, the third, which is the hypothenuse, joining them, will express the length of the foreshortened line.*

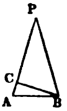


Fig. 487.

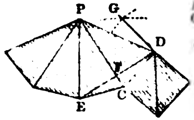


Fig. 488.

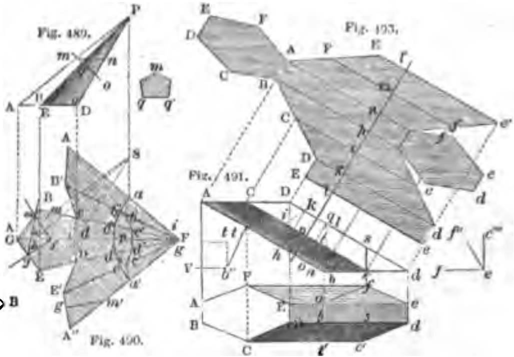


Fig. 492.

1160. In the application of this rule to the oblique pyramid of *fig.* 489., the position of the point P (*fig.* 490.) must be shown on the plan or horizontal projection answering to the apex of the pyramid, and from this point perpendicular to the face CD on the same side the perpendicular PG must be drawn. Then from the point P as a centre describe the arcs B*b*, C*c*, which will transfer upon PG the horizontal projections of the inclined arrisses AP, EP, and DP; and raising the perpendicular PS equal to the height of the apex P of the pyramid above the plane of projection, draw the lines S*a*, S*b*, S*c*, which will give the real lengths of all the edges or arrisses of the pyramid.

1161. We may then obtain the triangles which form the developement of this pyramid, by describing from C as a centre with the radius S*c*, the arc *ig*, and from the point D another arc intersecting the other in F. Drawing the lines CF, DF, the triangles CFD will be the developement of the side DC. To obtain that answering to BC, from the points F and C with S*b* and B*c* as radii, describe arcs intersecting in B′ and draw B′F and CB′: the triangle FCB′ will be the developement of the face answering to the side B*c*.

1162. We shall find the triangle FA′B′, by using the lengths SA and BA to find the points B′ and F, which will determine the triangle corresponding to the face AB, and lastly the triangles FDE′ and FE′A″ corresponding to the faces DE, AE by using the lengths S*b*, DE and SA, AE. The whole developement AEDE′A″F, A′B′, CBA being bent on the lines B′F*c*F, CD, DF, and EF will form the inclined figure represented in *fig.* 489.

1163. If this pyramid be truncated by the plane *mn*, parallel to the base, the contour resulting from the section may be traced on the developement by producing P*m* from F to *a*, and drawing the lines *ab*, *bc*, *cd*, *de* and *ea*″ parallel to A′B′, B′C, CD, DE′ and E′A″.

1164. But if the plane of the section be perpendicular to the axis, as *mo*, from the point F with a radius equal to P*o* describe an arc of a circle, in which inscribe the polygon *ab″c′d′e″a″*. Then the polygon *oqmq′o′* is the plane of the section induced by the line *mo*.

DEVELOPEMENT OF RIGHT AND OBLIQUE PRISMS.

1165. In a right prism, the faces being all perpendicular to the bases which terminate the solid, the developements are rectangles, consisting of all these faces joined together and enclosed by two parallel right lines equal to the contours of the bases.

1166. When a prism is inclined, the faces form different angles with the lines of the contours of the bases, whence results a developement whose extremities are terminated by lines forming portions of polygons.

1167. We must first begin by tracing the profile of the prism parallel to its degree of inclination (*fig.* 491.). Having drawn the line C*c*, which represents the inclined axis of the prism in the direction of its length, and the lines AD, *bd*, to show the surfaces by which it is terminated, describe on such axis the polygon which forms the plane of the prism *h*, *i*, *k*, *l*, *m* perpendicular to the axis. Producing the sides *kl*, *hn* parallel to the axis to meet the lines AD, *bd*, they will give the four arrisses of the prism, answering to the angles *h*, *n*, *k*, *l*; and the line C*c* which loses itself in the axis will give the arrisses *im*.

1168. It must be observed, that in this profile the sides of the polygon *h*, *i*, *k*, *l*, *m* give the width of the faces round the prism, and the lines A*b*, C*c*, D*d* their length. From this profile follows the horizontal projection (*fig.* 492.) wherein the lengthened polygons reprosent the bases of the prism. In order to obtain the developement of this inclined prism; so that being bent up it may form the figure, from the middle of Cc, *fig.* 491. a perpendicular *o*, *p*, *q* must be raised, produced to *l*, *l'*, *fig.* 493.; on this line must be transferred the widths of the faces shown by the polygon *h*, *i*, *k*, *l*, *m*, *n*, of *fig.* 491. in *l*, *k*, *i*, *h*, *n*, *m*, *l'*, *fig.* 493.: through these points parallel to the axis, lines are to be drawn, upon which *q*D of *fig.* 491. must be laid from *l* to E, from *k* to D, and from *l'* to E', *fig.* 493.; *p*C, *fig.* 491., must be laid from *i* to C, and from *m* to F in *fig.* 493.

*o*A, *fig.* 491., is to be laid from *h* to B and from *n* to A, *fig.* 493., which will give the contour of the developement of the upper part by drawing the lines ED, DCB, BA, AFE', *fig.* 492.

To obtain the contour of the base, *qd* of *fig.* 491. must be transferred from *l* to *q*, from *k* to *d*, and from *l'* to *e'*, *fig.* 493.

pc from *fig.* 491. from *i* to *c* and from *m* to *f* (*fig.* 493.); lastly, *ob* of *fig.* 16. must be transferred from *h* to *b* and from *n* to *a* (*fig.* 493.) and drawing the lines *ed*, *bcd*, *ba*, and *afe'*, the contour will be obtained.

1169. The developement will be completed by drawing on the faces BA and *ba*, elongated polygons similar to ABCDEF and *abcdef* of *fig.* 491. and of the same size.

DEVELOPEMENT OF RIGHT AND OBLIQUE CYLINDERS.

1170. Cylinders may be considered as prisms whose bases are formed by polygons of an infinite number of sides. Thus, graphically, the developement of a right cylinder is obtained, by a rectangle of the same height, having in its other direction the circumference of the circle which serves as its base measured by a greater or less number of equal parts.

1171. But if the cylinder is oblique (*fig.* 494.), we must take the same measures as for the prism, and consider the inclination of it. Having described centrally on its axis the circle or ellipsis which forms its perpendicular thickness in respect of the axis, the circumference must be divided into an equal number of equal parts, as, for instance, twelve, beginning from the diameter and drawing from the points of division the parallels to the axis HA, *bi*, *ck*, *dl*, *em*, *fm*, GO, which will give the projection of the bases and the general developement.

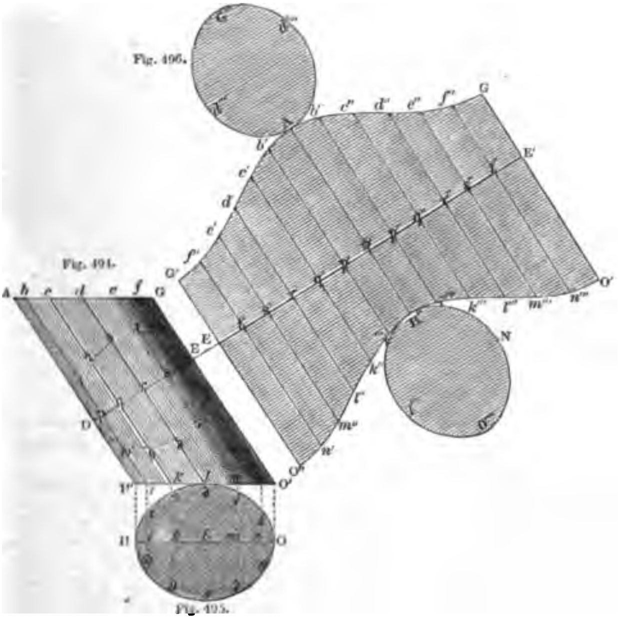


Fig. 496.
Fig. 494.
Fig. 495.

1172. For the projection of the bases on an horizontal plane, it is necessary that from the points where the parallels meet the line of the base HO, indefinite perpendiculars should be let fall, and after having drawn the line H', O', parallel to HO upon these perpendiculars above and below the parallel, must be transferred the size of the ordinates of the circle or ellipsis traced on the axis of the cylinder, that is, *p*1 and *p*10 to *i*′1, and *i*′10 : *q*2 and *q*9 in *k*′2 and *k*′*q*, &c. In order to avoid unnecessary repetition, the *figs*. 494, 495, 496. are similarly figured, and will by inspection indicate the corresponding lines.

1173. In the last figure the line E′E′ is the approximate developement of the circumference of the circles which follow the section DE perpendicular to the axis of the cylinder, divided into 12 equal parts, *fig*. 494. For which purpose there have been transferred upon this line on each side of the point D, six of the divisions of the circle, and through these points have been drawn an equal number of indefinite parallels to the lines traced upon the cylinder in *fig*. 494. : then taking the point D′ as correspondent to D, the length of these lines is determined by transferring to each of them their relative dimensions, measured from DG in AG for the superior surface of the cylinder, and from DE to HO for the base.

1174. In respect of the two elliptical surfaces which terminate this solid, what has been above stated, on the manner of describing a curve by means of ordinates, will render further explanation on that point needless.

DEVELOPEMENT OF RIGHT AND OBLIQUE CONES.

1175. The reasoning which has been used in respect of cylinders and prisms, is applicable to cones and pyramids.

1176. In right pyramids, with regular and symmetrical bases, the edges or arrisses from the base to the apex are equal, and the sides of the polygon on which they stand being equal, their developement must be composed of similar isosceles triangles, which in their union will form throughout, part of a regular polygon, inscribed in a circle whose inclined sides will be the radii. Thus, in considering the base of the cone A′B′ (*fig*. 497.) as a regular polygon of an infinite number of sides, its developement becomes a sector of a circle A″B″B‴C″ (*fig*. 498.) whose radius is equal to the side A′C′ of the cone, and the arc equal to the circumference of the circle which is its base.

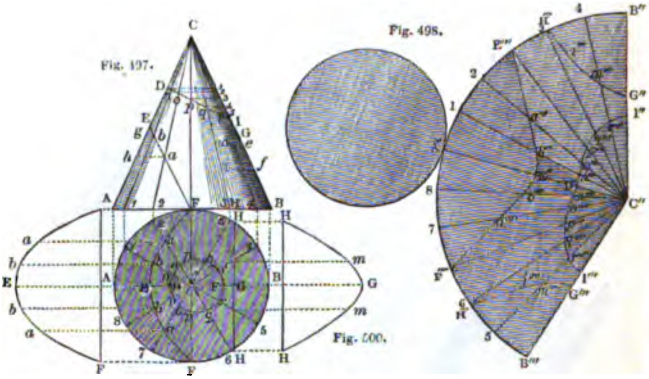


Fig. 499.

Fig. 501.

1177. Upon this may be traced the developement of the curves which would result from the cone cut according to the lines DI, EF, and GH, which are the ellipsis, the parabola, and the hyperbola. For this purpose the circumference of the base of the cone must be divided into equal parts; from each point lines must be drawn to the centre C, representing in this case the apex of the cone. Having transferred, by means of parallels, to FF, the divisions of the semi-circumference AFB of the plan, upon the line A′B′, forming the base of the vertical projection of the cone (*fig*. 497.) to the points 1′2′, F3′, and 4′, which, because of the uniformity of the curvature of the circle will also represent the divisions on the plan marked 8, 7F′, 6, and 5; from the summit C′ in the elevation of the cone, the lines C′1′, C′2′, C′F, C′3′, C′4′ are to be drawn, cutting the plans DI, EF, and GH of the ellipse, of the parabola, and of the hyperbola; then by the assistance of these intersections their figures may be drawn on the plan, the first in D′*p*′I′*p*″; the second in FE′F′; the third in H′GH″.

1178. To obtain the points of the circumference of the ellipse upon the developement (*fig*. 498.), from the points *n*, *o*, *p*, *q*, *r* of the line DI (*fig*. 497.), draw parallels to the base for the purpose of transferring their heights upon C′B′ at the points 1, 2, 3, 4, 5. Then transfer C′D upon the developement, in C″*n*‴, C″*o*‴, C″*p*‴, C″*q*‴, C″*r*‴; and in the same order below, C″*n*⁗, C″*o*⁗, C″*p*⁗, C′*q*⁗, C″*r*⁗; and CI from C″ in I″ and I‴. The curve passing through these points will be the developement of the circumference of the ellipse indicated in *fig.* 497. by the right line DI, which is its great axis.

1179. For the parabola (*fig.* 499.) on the side C'A' (*fig.* 497.), draw *bg* and *ah*; then transfer C'E on the developement in C"E"; C'*g* from C" to *b*''' and *b*''''; C'*h*, from C" to *a*''' and *a*''''; and through the points F", *a*''', *b*''', E", *b*'''', *a*'''', F''', trace a curve, which will be the developement of the parabola shown in *fig.* 497. by the line EF.

1180. For the hyperbola, having drawn through the points *m* and *i*, the parallels *me*, *if*, transfer C'G from C" to G", and from C" to G''' of the developement, C'*e* from C" to *m*''' and *m*'''', C'*f* from C" to *i*''' and *i*''''; and after having transferred 3H' and 6H" of the plan to the circumference of the developement, from 3 to H''', and from 6 to H'''', by the aid of the points H''', *i*", *m*''', G" and H'''', *i*'''', *m*'''', G''', draw two curves, of which each will be the developement of one half of the hyperbola represented by the right lines GH and H'H", *figs.* 497. and 500., and by *fig.* 501.

1181. The mode of finding the developement of an oblique cone, shown in *figs.* 502, 503, 504, 505. differs, as follows, from the preceding. 1. From the position of the apex C upon the plan 503., determined by a vertical let fall from such apex in *fig.* 502. 2. Because the line DI of this figure, being parallel to the base, gives for the plan a circle instead of an ellipsis. 3. Because in finding the lengthened extent of the right lines drawn from the apex of the cone to the circumference of the base, divided into equal parts, *fig.* 504. is introduced to bring them together in order to avoid confusion, these lines being all of a different size on account of the obliquity of the cone. In this figure the line CC' shows the perpendicular height of the apex of the cone above the plan; so that by transferring from each side the projections of these lines taken on the plan from the point C to the circumference, we shall have CA", C1, C2, CF", C3, C4, CB', on one side, and CA', C8, C7, CF, C6, C5, and CB" on the other; lastly, from the point C drawing lines to all these points, they will give the edges or arrisses of the inscribed pyramid, by which the developement in *fig.* 505. is obtained. Having obtained the point C" representing the apex, a line is to be drawn through it equal to CA" (*fig.* 504.); then with one of the divisions of the base taken on the plan, such as A1, it must be laid from the point A of the developement of the section; then taking C'1 of *fig.* 504., describe from the point C" another arc which will cross the former, and will determine the point 1 of the developement. Continuing the operations with the constant length A1 and the different lengths C2, CF', C3, &c., taken from *fig.* 504. and transferred to C"2, C"F, C"3, &c. of the developement, the necessary points will be obtained for tracing the curve B"AB''', representing the contour of the oblique base of the cone.

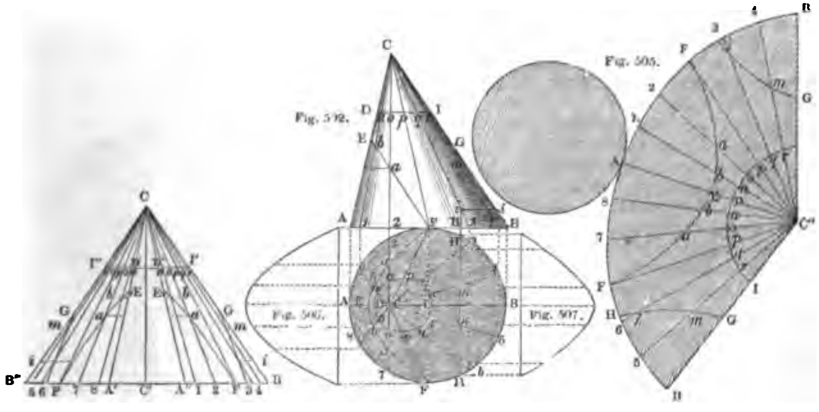


Fig. 504. Fig. 503.

1182. We obtain the developement of the circle shown by the line DI of *fig.* 502. parallel to that of the base AB, by drawing another line I'D'D"I" (*fig.* 504.) at the same distance from the summit C, cutting all the oblique lines that have served for the preceding developement; and on one side, CD", C*n*, C*o*, C*p*, C*q*, C*r*, CI", must be carried to *fig.* 505., from C" to D", *n*, *o*, *p*, *q*, *r*, and on the other from C" to *n*, *o*, *p*, *q*, *r*, and I'''', on *fig.* 505. The curve line passing through these points will be the developement of this circle.

1183. To trace upon the developement the parabola and hyperbola shown by the lines EF, G3 of *fig.* 502., from the points E*ba*, G*mi* draw parallels to the base AB, which, transferred to *fig.* 504., will indicate upon corresponding lines the real distance of these points from the apex C, which are to be laid in *fig.* 505. from C" to E, *b*, *a*, *b* and *a* for the parabola; and from C″ to G, *m*, *i* on one side, and on the other to G, *m*, *i*, for the hyperbola. Each of these is represented in *figs.* 506. and 507.

DEVELOPEMENT OF BODIES OR SOLIDS WHOSE SURFACES HAVE A DOUBLE CURVATURE.

1184. The developement of the sphere and other bodies whose surface has a double flexure would be impossible, unless we considered them as consisting of a great number of plane faces or of simple curvatures, as the cylinder and the cone. Thus a sphere or spheroid may be considered, — I. As a polyhedron of a great number of plane faces formed by truncated pyramids whose base is a polygon, as *fig.* 508. II. By truncated cones, forming zones, as in *fig.* 509. III. By parts of cylinders cut in gores, forming flat sides that diminish in width, shown by *fig.* 510.

1185. In reducing the sphere or spheroid to a polyhedron with flat faces, the developement may be accomplished in two ways, which differ only by the manner in which the faces are developed.

1186. The most simple method of dividing the sphere to reduce it to a polyhedron is that of parallel circles crossed by others perpendicular to them, and intersecting in two opposite points, as in the common geographical globes. If, instead of the circle, the polygons are supposed of the same number of sides, a polyhedron will be the result, similar to that represented by *fig.* 508., whose half ADB shows the geometrical elevation, and AEB the plan of it.

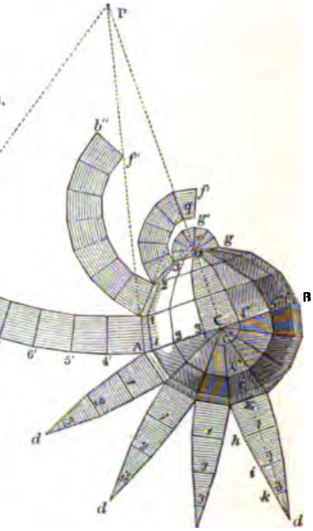


Fig. 508.

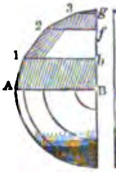


Fig. 509.

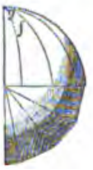


Fig. 510.

1187. For the developement, produce A1, 12, 23, so as to meet the produced axis CP in order to obtain the summits P, *q*, *r*, D of the truncated pyramids which form the semi-polyhedron ADB; then from the points P, *q*, *r*, with the radii PA, P1, *q*1, *q*2, *r*2, *r*3 and D3, describe the indefinite arcs AB′, 1*b*′, 1*b*″, 2*f*′, 2*f*″, 3*g*′, and 3*g*, upon which, after having transferred the divisions of the demi-polygons AEB, 1*e*6‴, 2*e*′5‴, 3*e*″, 4″, from all the transferred points, as A, 4′, 5′, 6′, 7′, 8′, 9′, B′, for each truncated pyramid draw lines to the summits P*qr*D, and other lines which will form inscribed polygons in each of the arcs AB′, 1*b*′, 1*b*″, &c. These lines will represent for each band or zone the faces of the truncated pyramids whereof they are part.

1188. We may arrive at the same developement by raising upon the middle of each side of the polygon AEB indefinite perpendiculars, upon which must be laid the height of the faces of the elevation in 1, 2, 3, 4; through which points draw parallels to the base, upon which transfer the widths of each of the faces taken on the plan, whereby trapezia will be formed, and triangles similar to those found in the first developement, but ranged in another manner. This last developement, which is called in *gores*, is more suitable for geographical globes; the other method, for the formation of the centres, moulds, and the like, of spherical vaults.

1189. The developement of the sphere by conic zones (*fig.* 509.) is obtained by the same process as that by truncated pyramids, the only difference being, that the developement of the arrisses AB, 1*b*, 2*f*, 3*g*, are arcs of circles described from the summits of cones, instead of being polygons.

1190. The developement of the sphere reduced to portions of cylinders cut in gores (*fig.* 510.) is conducted in the second manner, but instead of joining with lines the points 6, *h*, *i*, *k*, *d*, (*fig.* 508.) they must be united by a curve. This last method is useful in drawing the caissons or pannels in spherical or spheroidal vaults.

OF THE ANGLES OF PLANES OR SURFACES BY WHICH SOLIDS ARE BOUNDED.

1191. In considering the formation of solids, we have already noticed three sorts of angles, viz. plane angles, solid angles, and the angles of planes. The two first have been treated of in the preceding sections, and we have now to speak of the third, which must not be confounded with plane angles. Of these last, we have explained that they are formed by the lines or arrisses which bound the faces of a solid; but the angles of planes, whereof we are about to speak, are those formed by the meeting of two surfaces joining in an edge.

1192. The inclination of one plane ALDE to another ALCB (*fig.* 511.) is measured by two perpendiculars FG, FH raised upon each of these planes from the same point F of the line or arris AL formed by their union.

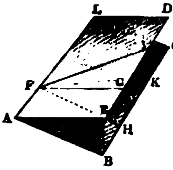


Fig. 511.

1193. It is to be observed, that this angle is the greatest of all those formed by lines drawn from the point F upon these two planes; for the lines FG, FH being perpendicular to AL, common to both the planes, they will be the shortest that can be drawn from the point F to the sides ED, BC, which we suppose parallel to AL; thus their distance GH will be throughout the same, whilst the lines FI, FK will be so much the longer as they extend beyond the perpendiculars FG, FH, and we shall always have KI equal to GH, and consequently the angle IFK so much smaller than GFH as it is more distant.

1194. Thus, let a rectangular surface be folded perpendicularly to one of its sides so that the contours of the parts separated by the fold may fall exactly on each other. If we raise one of them, so as to move it on the fold as on a hinge, and so as to make it form all degrees of angles, we shall see that each of the central extremities of the moveable part is always in a plane perpendicular to the part that is fixed.

1195. This property of lines moving in a perpendicular plane, furnishes a simple method of finding the angles of planes of all sorts of solids whose vertical and horizontal projections or whose developements are known.

1196. Thus, in order to find the angles formed by the tetrahedron or pyramid on a triangular base (*fig.* 477.), we must for the angles of the base with the sides, let fall from the angles ABC perpendiculars to the sides *ac*, *cb*, and *ab*, which meet at the centre of the base in D. It is manifest from what has just been said on this subject, that if the three triangles are made to move, their angles at the summit A, B, C will not be the vertical planes shown by the lines AD, DB, DC, and that they will meet at the extremity of the vertical, passing through the intersection of these planes at the point D. Thus we obtain for each side a rectangular triangle, wherein two sides are known, namely, for the side *cb*, the hypothenuse *ed*, and the side *e*D. Thus raising from the point D an indefinite perpendicular, if from the point *e* with *e*B for a radius an arc is described cutting the perpendicular in *d*, and the line *de* be drawn, the angle *de*D will be that sought, and will be the same for the three sides if the polyhedron be regular; otherwise, if it is not, the operation must be repeated for each.

1197. These angles may be obtained with great accuracy by taking *de*, or its equal *e*B, for the whole sine; then *de* : *e*D :: sine : sine 19° 28′, whose complement 70° 32′ will, if the polyhedron be regular, be the angle sought. In this case, all the sides being equal, and each being capable of serving as base, the angles throughout are equal. In respect of the cube (*figs.* 479. and 483.) whose faces are composed of equal squares, and whose angles are all right angles, it is evident that no other angles can enter into their combination with each other.

1198. To obtain the angle formed by the faces of the octahedron (*fig.* 480.) from the points C and D: with a distance equal to a vertical dropped upon the base of one of the triangles of its developement (*fig.* 484.), describe arcs crossing each other in F; and the angle CFD will be equal to that formed by the faces of the polyhedron, and will be found by trigonometry to be 70° 32′. In the dodecahedron (*fig.* 481.), the angle formed by the faces will be found by drawing upon its projection the lines DA, and producing the side B to E, determined by an arc made from the point D with a radius equal to BA. The angle sought will be found to be 108 degrees.

1199. For the icosahedron (*fig.* 482.), draw the parallels A*a*, B*b*, C*c*, and after having made *bc* parallel and equal to BC, with a radius equal thereto, describe an arc cutting in *a* the parallel drawn from the point A; the angle *abc* will be equal to that formed by the sides of the polygon, which by trigonometry is found to be 108 degrees, as in the dodecahedron.

1200. For the pyramid with a quadrangular base (*fig.* 487.) the angle of each face with the base is equal to PAB or PBA, because this figure, which represents its vertical projection, is in a plane parallel to that within which will be found the perpendiculars dropped from the summit on the lateral faces of the base.

1201. In order to obtain the angles which the inclined sides form with one another, draw upon the developement (*fig.* 488.) the line ED, which, because the triangles PEC, PCD are equal and isosceles, will be perpendicular to the line PC, representing one of the arrisses which are formed. Then from the point D with a radius equal to DF, and from the point C with a radius equal to the diagonal AD (of the square representing the square of the base) describe arcs intersecting each other. The angle FDG will be the angle sought. We may suppose it taken along the line BC traced in *fig.* 487.

1202. In order to obtain the angles formed by the faces of an oblique pyramid (*fig.* 489.), through some point *q* of the axis draw the perpendicular *mo*, showing the base *oqmq'o'* of the right pyramid *mpo*, whose developement is shown in *fig.* 490., by the portion of the polygon *a*, *b''*, *c''*, *e''*, *d''*, *a'*F.

1203. By means of this base and the part developed, proceeding as we have already explained for the right pyramid, we shall find the angles formed by the meeting of the faces, and they will differ but little from those of the little polygon *oqmq'o'*.

1204. In respect to the angles formed by the faces inclined to the base, that of the face answering to the side D*e* of the base is expressed by the angle ADP of the vertical projection, *fig.* 489.

1205. As to the other faces, for instance, that which corresponds to the side AE of the base (*fig.* 490.), through any point *g* draw *gf* perpendicular to it, meeting the line AF, showing the projection of one of the sides of the inclined face; upon the developement of this face, expressed by A''E'F, raise at the same distance from the point E' another perpendicular *g'm'*, which will give the prolongation of the line shown on the base by A*f*. If we transfer A''*m* of the developement upon A*m*, which expresses the inclination of the arris represented by this line, we shall have the perpendicular height *mf* of the point *m* above the base, which, being transferred from *fm''* upon a perpendicular to *gf*, we shall have the two sides of a triangle whose hypothenuse *gm''* will give *m''gf*, the angle sought.

1206. In the oblique prism (*fig.* 491.), the angles of the faces are indicated by the plan of the section perpendicular to the axis, represented by the polygon *hiklmn*.

1207. Those of the sides perpendicular to the plan of the inclination of the axis are expressed by the angles D*db*, A*bd* of the profile in the figure last named.

1208. In order to obtain the angles formed with the other sides, for instance C*c*D*d* and C*c*A*b*, draw the perpendiculars *csbt*, whose projection in plan are indicated by *s''c'* and *b't'*, then upon *fc*, drawn aside, raise a perpendicular *c''c'''* equal to *cs* of the profile, *fig.* 491. Through the point *c'''* draw a line parallel to *fc*, upon which, having transferred *c's'* of the projection in plan (*fig.* 492.), draw the hypothenuse *s''c''*, and it will give the angle *s''e''f* formed by the face C*c*D*d* with the inferior base.

1209. To obtain the angles of the face C*c*A*b*, raise upon F*b''*, drawn on one side, a perpendicular *b''t'''*, equal to *bt* (*fig.* 492.), and drawing as before a parallel to *b''* through the point *t'''*, transfer *b't'* of *fig.* 492. to *t'''t''*; and drawing *t''b''*, the angle *t''b''*F is that required.

1210. As the bases of this prism are parallel, these faces necessarily form the same angles with the superior base.

1211. An acquaintance with the angles of planes is of the greatest utility in the preparation of stone, and a thorough acquaintance with it will well repay the architectural student for the labour he may bestow on the subject.

Sect. VII.

MENSURATION.

1212. The area of a plane figure is the measure of its surface or of the space contained within its extremities or boundaries, without regard to thickness. This area, or the content of the plane figure, is estimated by the number of small squares it contains, the sides of each whereof may be an inch, a foot, a yard, or any other fixed quantity. Hence the area is said to consist of so many square inches, feet, yards, &c., as the case may be.

1213. Thus if the rectangle to be measured be ABCD (*fig.* 512.), and the small square E, whose side we will suppose to be one inch, be the measuring unit proposed; then, as often as such small square is contained in the rectangle, so many square inches are said to be contained in the rectangle. Here it will be seen by inspection that the number is 12; that the side DC or AB, which is 4 times the length of the measuring unit, multiplied by the number of times 3, which the length of the measuring unit is contained in AD or BC, will give 12 for the product.

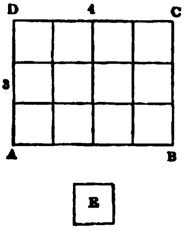


Fig. 512.

1214. **Problem I.** *To find the area of a parallelogram, whether it be a square, a rectangle, a rhombus, or a rhomboid.*

Multiply the length by the perpendicular breadth or height, and the product will be the area.

Example 1. Required the area of a parallelogram whose length is 12·25 feet, and height 8·5 feet.

$$12·25 \times 8·5 = 104·125 \text{ feet, or } 104 \text{ feet } 1\tfrac{1}{2} \text{ inches.}$$

Example 2. Required the content of a piece of land in the form of a rhombus whose length is 6·20 chains, and perpendicular height 5·45.

Recollecting that 10 square chains are equal to a square acre, we have,

$6·20 \times 5·45 = 33·79$ and $\frac{33·79}{10} = 3·379$ acres, which are equal to 3 acres, 1 rood, $20\frac{64}{100}$ perches.

Example 3. Required the number of square yards in a rhomboid whose length is 37 feet, and breadth 5 feet 3 inches (= 5·25 feet).

Recollecting that 9 square feet are equal to 1 square yard, then we have

$$37 \times 5·25 = 194·25, \text{ and } \frac{194·25}{9} = 21·584 \text{ yards.}$$

1215. **PROBLEM** II. *To find the area of a triangle.*

Rule 1. Multiply the base by the perpendicular height, and take half the product for the area. Or multiply either of these dimensions by half the other. The truth of this rule is evident, because all triangles are equal to one half of a parallelogram of equal base and altitude. (See Geometry, 904.)

Example 1. To find the area of a triangle whose base is 625 feet, and its perpendicular height 520 feet. Here,

$$625 \times 260 = 162500 \text{ feet, the area of the triangle.}$$

Rule 2. When two sides and their contained angle are given: multiply the two given sides together, and take half their product; then say, as radius is to the sine of the given angle, so is half that product to the area of the triangle. Or multiply that half product by the natural sine of the said angle for the area. This rule is founded on proofs which will be found in Chap. IV., on which it is unnecessary here to say more.

Example. Required the area of a triangle whose sides are 30 and 40 feet respectively, and their contained angles 28° 57′.

By natural numbers: —

First, $\frac{1}{2} \times 40 \times 30 = 600$.
Then, $1 : 600 :: ·484046 (\sin. 28° 57′) : 290·4276$.

By logarithms: —

$$\begin{array}{l} \text{Sin. } 28° 57′ = 9·684887 \\ \text{Log. of } 600 = 2·778151 \\ \hline 2·463038 = 290·4276, \text{ as above.} \end{array}$$

Rule 3. When the three sides are given, take half the sum of the three sides added together. Then subtract each side severally from such half sum, by which three remainders will be obtained. Multiply such half sum and the three remainders together, and extract the square root of the last product, which is the area of the triangle. This rule is founded on one of the theorems in Trigonometry to be found in the section relating to that branch of the subject.

Example. Required the area of a triangle whose three sides are 20, 30, and 40.

$20 + 30 + 40 = 90$, whose half sum is 45.

$45 - 20 = 25$, first remainder; $45 - 30 = 15$, second remainder; $45 - 40 = 5$, third remainder.

Then, $45 \times 25 \times 15 \times 5 = 84375$, whose root is 290·4737, area required.

1216. **PROBLEM** III. *To find the area of a trapezoid.*

Add together the parallel sides, multiply their sum by the perpendicular breadth or distance between them, and half the product is the area. (See Geometry, 932.)

Example 1. Required the area of a trapezoid whose parallel sides are 750 and 1225, and their vertical distance from each other 1540.

$$1225 + 750 = 152075, \text{ the area.}$$

Example 2. Required the area of a trapezoid wherein

AP is 110 feet,
AQ 745 feet,
AB 1110 feet,
CP 352 feet,
DQ 595 feet.

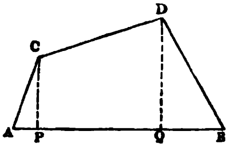


Fig. 518.

Therefore, $QB = AB - AQ = 1110 - 745 = 365$,
And $PQ = AB - AP - QB = 1110 - 110 - 365 = 635$.

For PCDQ, $595 + 352 \times 635 \div 2 = 300672{\cdot}5$
For the triangle ACP, $176 \times 110 = 19360$
For the triangle DQB, $\frac{365 \times 595}{2} = 108587{\cdot}5$

Area $= 428620{\cdot}0$ feet.

1217. **Problem IV.** *To find the area of any trapezium.*

Divide the trapezium into two triangles by a diagonal; then find the areas of the two triangles, and their sum is the area.

Observation. If two perpendiculars be let fall on the diagonal from the other two opposite angles, then add these two perpendiculars together, and multiply that sum by the diagonal. Half the product is the area of the trapezium.

Example. Required the area of a trapezium whose diagonal is 42, and the two perpendiculars on it 16 and 18.

Here, $16 + 18 = 34$, whose half $= 17$;
Then, $42 \times 17 = 714$, the area.

1218. **Problem V.** *To find the area of an irregular polygon.*

Draw diagonals dividing the proposed polygon into trapezia and triangles. Then, having found the areas of all these separately, their sum will be the content required of the whole polygon.

Example. Required the content of the irregular figure ABCDEFGA (*fig.* 514.), wherein the following diagonals and perpendiculars are given.

$AC = 55$, $GC = 44$, $Bn = 18$, $Ep = 8$,
$FD = 52$, $Gm = 13$, $GO = 12$, $Dq = 23$.
And $55 \times 9 = 495$
$55 \times 6{\cdot}5 = 357{\cdot}5$
$44 \times 11{\cdot}5 = 506$
$52 \times 6 = 312$
$52 \times 4 = 208$

$1878{\cdot}5$, area required.

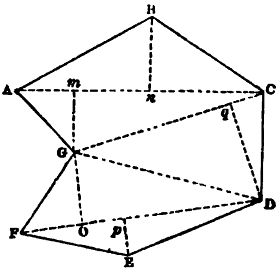


Fig. 514.

1219. **Problem VI.** *To find the area of a regular polygon.*

Rule 1. Multiply the perimeter of the polygon, or sum of its sides, by the perpendicular drawn from its centre on one of its sides, and take half the product of the area; which is in fact resolving the polygon into so many triangles.

Example. Required the area of the regular pentagon ABCDE (*fig.* 515.), whose side AB or BC, &c. is 25 ft., and perpendicular OP 17·2 ft.

Here $\frac{25 \times 5}{2} = 62{\cdot}5 =$ half the perimeter, and $62{\cdot}5 \times 17{\cdot}2 = 1075$ square feet area required.

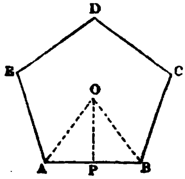


Fig. 515.

Rule 2. Square the side of the polygon, and multiply the square by the tabular area or multiplier set against its name in the following table, and the product will be the area. This rule is founded on the property, that like polygons, being similar figures, are to one another as the squares of their like sides. Now the multipliers of the table are the respective areas of the respective polygons to a side $= 1$; whence the rule is evident. In the table is added the angle OBP in the several polygons.

No. of Sides.	Names.	Multipliers.	Angle OBP.
3	Trigon or equilateral triangle	0·4330127	30°
4	Tetragon or square - -	1·0000000	45°
5	Pentagon - - - -	1·7204774	54°
6	Hexagon - - - -	2·5980762	60°
7	Heptagon - - - -	3·6339124	$64\frac{2}{7}$°
8	Octagon - - - -	4·8284271	$67\frac{1}{2}$°
9	Nonagon - - - -	6·1818242	70°
10	Decagon - - - -	7·6942088	72°
11	Undecagon - - -	9·3656399	$73\frac{7}{11}$°
12	Dodecagon - - -	11·1961524	75

Example. Required the area of an octagon whose side is 20 feet.

Here $20^2=400$, and the tabular area 4·8284271;
Therefore 4·8284271 × 400 = 1931·37084 feet, area required.

1220. **Problem VII.** *To find the diameter and circumference of any circle, either from the other.*

Rule 1. As 7 is to 22, or as 1 is to 3·1416, so is the diameter to the circumference. Or as 22 is to 7, so is the circumference to the diameter.

Example. Required the circumference of a circle whose diameter is 9.

Here $7 : 22 :: 9 : 28\frac{2}{7}$; or, $\frac{22 \times 9}{7} = 28\frac{2}{7}$, the circumference required.

Required the diameter of a circle whose circumference is 36.

Here $22 : 7 :: 36 : 11\frac{10}{22}$; or, $\frac{36 \times 7}{22} = 11\frac{10}{22}$, the diameter required.

1221. **Problem VIII.** *To find the length of any arc of a circle.*

Rule 1. Multiply the decimal ·01745 by the number of degrees in the given arc, and that by the radius of the circle; then the last product will be the length of the arc. This rule is founded on the circumference of a circle being 6·2831854 when the diameter is 2, or 3·1415927 when the diameter is 1. The length of the whole circumference then being divided into 360 degrees, we have 360° : 6·2831854 :: 1° : ·01745.

Example. Required the length of an arc of 30 degrees, the radius being 9 feet.

Here ·01745 × 30 × 9 = 4·7115, the length of the arc.

Rule 2. From 8 times the chord of half the arc subtract the chord of the whole arc, and one third of the remainder will be the length of the arc nearly.

Example. Required the length of an arc DCE (*fig.* 516.) whose chord DE is 48, and versed sine 18.

Here, to find DC, we have $24^2 + 18^2 = 576 + 324 = 900$, and $\sqrt{900} = 30 = $ DC.

Whence $\frac{30 \times 8 - 48}{3} = \frac{240 - 48}{3} = \frac{192}{3} = 64$, the length of the arc required.

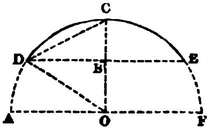


Fig. 516.

1222. **Problem IX.** *To find the area of a circle.*

Rule 1. Multiply half the circumference by half the diameter. Or multiply the whole circumference by the whole diameter, and take ¼ of the product.

Rule 2. Square the diameter, and multiply such square by ·7854.

Rule 3. Square the circumference, and multiply that square by the decimal ·07958.

Example. Required the area of a circle whose diameter is 10, and its circumference 31·416.

By rule 1., $\frac{31 \cdot 416 \times 10}{4} = 78 \cdot 54$.
By rule 2., $10^2 \times \cdot 7854 = 100 \times \cdot 7854 = 78 \cdot 54$.
By rule 3., 31·416 × 31·416 × ·07958 = 78·54.

So that by the three rules the area is 78·54.

1223. **Problem X.** *To find the area of a circular ring, or of the space included between the circumferences of two circles, the one being contained within the other.*

Rule. The difference between the areas of the two circles will be the area of the ring. Or, multiply the sum of the diameters by their difference, and this product again by ·7854, and it will give the area required.

Example. The diameters of two concentric circles being 10 and 6, required the area of the ring contained between their circumferences.

Here 10 + 6 = 16, the sum, and 10 − 6 = 4, the difference.
Therefore ·7854 × 16 × 4 = ·7854 × 64 = 50·2656, the area required.

1224. **Problem XI.** *To find the area of the sector of a circle.*

Rule 1. Multiply the radius, or half the diameter, by half the arc of the sector for the area. Or multiply the whole diameter by the whole arc of the sector, and take ¼ of the product. This rule is founded on the same basis as that to Problem IX.

Rule 2. As 360 is to the degrees in the arc of the sector, so is the area of the whole circle to the area of the sector. This is manifest, because it is proportional to the length of the arc.

Example. Required the area of a circular sector whose arc contains 18 degrees, the diameter being 3 feet.

By the first rule, 3·1416 × 3 = 9·4248, the circumference.

360 : 18 :: 9·4248 : ·47124, the length of the arc.
·47124 × 3 ÷ 4 = 1·41372 ÷ 4 = ·35343, the area of the sector.

By the second rule, ·7854 × 3^2 = 7·0686, area of the whole circle.
360 : 18 :: 7·0686 : ·35343, the area of the sector.

1225. **Problem XII.** *To find the area of a segment of a circle.*

Rule 1. Find the area of the sector having the same arc with the segment by the last problem. Then find the area of the triangle formed by the chord of the segment and the two radii of the sector. Take the sum of these two for the answer when the segment is greater than a semicircle, and their difference when less than a semicircle.

Example. Required the area of the segment ACBDA (*fig.* 517.), its chord AB being 12, and the radius AE or CE 10.

As AE : sin. ∠ D 90° :: AD : sin. 36° : 52½ = 36·87 degrees in the arc AC.

Their double 73·74 degrees in arc ACB.

Now, ·7854 × 400 = 314·16, the area of the whole circle.

Therefore, 360' : 73·74 :: 314·16 : 64·3504, area of the sector ACBE.

Again, $\sqrt{AE^2 - AD^2} = \sqrt{100-36} = \sqrt{64} = 8 =$ DE.

Therefore, AD × DE = 6 × 8 = 48, the area of the triangle AEB.

Hence the sector ACBE (64·350), less triangle AEB (48) = 16·3504, area of segment ACBDA.

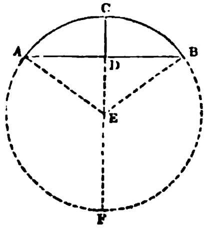


Fig. 517.

Rule 2. Divide the height of the segment by the diameter, and find the quotient in the column of heights in the following table. Take out the corresponding area in the next column on the right hand, and multiply it by the square of the circle's diameter for the area of the segment. This rule is founded on the principle of similar plane figures being to one another as the squares of their like lineal dimensions. The segments in the table are those of a circle whose diameter is 1. In the first column is contained the versed sines divided by the diameter. Hence the area of the similar segment taken from the table and multiplied by the square of the diameter gives the area of the segment to such diameter. When the quotient is not found exactly in the table, a proportion is used between the next less and greater area.

Example. As before, let the chord AB be 12, and the radius 10 or diameter 20. Having found as above DE = 8 : then CE − DE = CD = 10 − 8 = 2. Hence by the rule CD + CF = 2 + 20 = ·1, the tabular height; this being found in the first column of the table, the corresponding tabular area is ·040875; then ·040875 × 20^2 = ·040875 × 400 = 16·340, the area nearly the same as before.

Areas of the Segments of a Circle whose Diameter, Unity, is supposed to be divided into 1000 equal Parts.

Hght.	Area Seg.	Hght.	Area Seg.	Hght.	Area Seg.	Hght.	Area Seg.	Hght.	Area Seg.	Hght.	Area Seg.
·001	·000042	·022	·004322	·043	·011734	·064	·021168	·085	·032186	·106	·044522
·002	·000119	·023	·004618	·044	·012142	·065	·021659	·086	·032745	·107	·045139
·003	·000219	·024	·004921	·045	·012554	·066	·022154	·087	·033307	·108	·045759
·004	·000337	·025	·005230	·046	·012971	·067	·022652	·088	·033872	·109	·046381
·005	·000470	·026	·005546	·047	·013392	·068	·023154	·089	·034441	·110	·047005
·006	·000618	·027	·005867	·048	·013818	·069	·023659	·090	·035011	·111	·047632
·007	·000779	·028	·006194	·049	·014247	·070	·024168	·091	·035585	·112	·048262
·008	·000951	·029	·006527	·050	·014681	·071	·024680	·092	·036162	·113	·048894
·009	·001135	·030	·006865	·051	·015119	·072	·025195	·093	·036741	·114	·049528
·010	·001329	·031	·007209	·052	·015561	·073	·025714	·094	·037323	·115	·050165
·011	·001533	·032	·007558	·053	·016007	·074	·026236	·095	·037909	·116	·050804
·012	·001746	·033	·007913	·054	·016457	·075	·026761	·096	·038496	·117	·051446
·013	·001968	·034	·008273	·055	·016911	·076	·027289	·097	·039087	·118	·052090
·014	·002199	·035	·008638	·056	·017369	·077	·027821	·098	·039680	·119	·052736
·015	·002438	·036	·009008	·057	·017831	·078	·028356	·099	·040276	·120	·053385
·016	·002685	·037	·009383	·058	·018296	·079	·028894	·100	·040875	·121	·054036
·017	·002940	·038	·009763	·059	·018766	·080	·029435	·101	·041476	·122	·054689
·018	·003202	·039	·010148	·060	·019239	·081	·029979	·102	·042080	·123	·055345
·019	·003471	·040	·010537	·061	·019716	·082	·030526	·103	·042687	·124	·056003
·020	·003748	·041	·010931	·062	·020196	·083	·031076	·104	·043296	·125	·056663
·021	·004031	·042	·011330	·063	·020680	·084	·031629	·105	·043908	·126	·057326

Hght.	Area Seg.	Hght.	Area Seg.	Hght.	Area Seg	Hght.	Area Seg.	Hght.	Area Seg.	Hght.	Area Seg.
·127	·057991	·190	·103900	·253	·156149	·315	·212011	·377	·270951	·439	·331850
·128	·058658	·191	·104685	·254	·157019	·316	·212940	·378	·271920	·440	·332843
·129	·059327	·192	·105472	·255	·157890	·317	·213871	·379	·272890	·441	·333836
·130	·059999	·193	·106261	·256	·158762	·318	·214802	·380	·273861	·442	·334829
·131	·060672	·194	·107051	·257	·159636	·319	·215733	·381	·274832	·443	·335822
·132	·061348	·195	·107842	·258	·160510	·320	·216666	·382	·275803	·444	·336816
·133	·062026	·196	·108636	·259	·161386	·321	·217599	·383	·276775	·445	·337810
·134	·062707	·197	·109430	·260	·162263	·322	·218533	·384	·277748	·446	·338804
·135	·063389	·198	·110226	·261	·163140	·323	·219468	·385	·278721	·447	·339798
·136	·064074	·199	·111024	·262	·164019	·324	·220404	·386	·279694	·448	·340793
·137	·064760	·200	·111823	·263	·164899	·325	·221340	·387	·280668	·449	·341787
·138	·065449	·201	·112624	·264	·165780	·326	·222277	·388	·281642	·450	·342782
·139	·066140	·202	·113426	·265	·166663	·327	·223215	·389	·282617	·451	·343777
·140	·066833	·203	·114230	·266	·167546	·328	·224154	·390	·283592	·452	·344772
·141	·067528	·204	·115035	·267	·168430	·329	·225093	·391	·284568	·453	·345768
·142	·068225	·205	·115842	·268	·169315	·330	·226033	·392	·285544	·454	·346764
·143	·068924	·206	·116650	·269	·170202	·331	·226974	·393	·286521	·455	·347759
·144	·069625	·207	·117460	·270	·171089	·332	·227915	·394	·287498	·456	·348755
·145	·070328	·208	·118271	·271	·171971	·333	·228858	·395	·288476	·457	·349752
·146	·071033	·209	·119083	·272	·172867	·334	·229801	·396	·289453	·458	·350748
·147	·071741	·210	·119897	·273	·173758	·335	·230745	·397	·290432	·459	·351745
·148	·072450	·211	·120712	·274	·174649	·336	·231689	·398	·291411	·460	·352742
·149	·073161	·212	·121529	·275	·175542	·337	·232634	·399	·292390	·461	·353739
·150	·073874	·213	·122347	·276	·176435	·338	·233580	·400	·293369	·462	·354736
·151	·074589	·214	·123167	·277	·177330	·339	·234526	·401	·294349	·463	·355732
·152	·075306	·215	·123988	·278	·178225	·340	·235473	·402	·295330	·464	·356730
·153	·076026	·216	·124810	·279	·179122	·341	·236421	·403	·296311	·465	·357727
·154	·076747	·217	·125634	·280	·180019	·342	·237369	·404	·297292	·466	·358725
·155	·077469	·218	·126459	·281	·180918	·343	·238318	·405	·298273	·467	·359723
·156	·078194	·219	·127285	·282	·181817	·344	·239268	·406	·299255	·468	·360721
·157	·078921	·220	·128113	·283	·182718	·345	·240218	·407	·300238	·469	·361719
·158	·079649	·221	·128942	·284	·183619	·346	·241169	·408	·301220	·470	·362717
·159	·080380	·222	·129773	·285	·184521	·347	·242121	·409	·302203	·471	·363715
·160	·081112	·223	·130605	·286	·185425	·348	·243074	·410	·303187	·472	·364713
·161	·081846	·224	·131438	·287	·186329	·349	·244026	·411	·304171	·473	·365712
·162	·082582	·225	·132272	·288	·187234	·350	·244980	·412	·305155	·474	·366710
·163	·083320	·226	·133108	·289	·188140	·351	·245934	·413	·306140	·475	·367709
·164	·084059	·227	·133945	·290	·189047	·352	·246889	·414	·307125	·476	·368708
·165	·084801	·228	·134784	·291	·189955	·353	·247845	·415	·308110	·477	·369707
·166	·085544	·229	·135624	·292	·190864	·354	·248801	·416	·309095	·478	·370706
·167	·086289	·230	·136465	·293	·191775	·355	·249757	·417	·310081	·479	·371704
·168	·087036	·231	·137307	·294	·192684	·356	·250715	·418	·311068	·480	·372704
·169	·087785	·232	·138150	·295	·193596	·357	·251673	·419	·312054	·481	·373703
·170	·088535	·233	·138995	·296	·194509	·358	·252631	·420	·313041	·482	·374702
·171	·089287	·234	·139841	·297	·195422	·359	·253590	·421	·314029	·483	·375702
·172	·090041	·235	·140688	·298	·196337	·360	·254550	·422	·315016	·484	·376702
·173	·090797	·236	·141537	·299	·197252	·361	·255510	·423	·316004	·485	·377701
·174	·091554	·237	·142387	·300	·198168	·362	·256471	·424	·316992	·486	·378701
·175	·092313	·238	·143238	·301	·199085	·363	·257433	·425	·317981	·487	·379700
·176	·093074	·239	·144091	·302	·200003	·364	·258395	·426	·318970	·488	·380700
·177	·093836	·240	·144944	·303	·200922	·365	·259357	·427	·319959	·489	·381699
·178	·094601	·241	·145799	·304	·201841	·366	·260320	·428	·320948	·490	·382699
·179	·095366	·242	·146655	·305	·202761	·367	·261284	·429	·321938	·491	·383699
·180	·096134	·243	·147512	·306	·203683	·368	·262248	·430	·322928	·492	·384699
·181	·096903	·244	·148371	·307	·204605	·369	·263213	·431	·323918	·493	·385699
·182	·097674	·245	·149230	·308	·205527	·370	·264178	·432	·324909	·494	·386699
·183	·098447	·246	·150091	·309	·206451	·371	·265144	·433	·325900	·495	·387699
·184	·099221	·247	·150953	·310	·207376	·372	·266111	·434	·326892	·496	·388699
·185	·099997	·248	·151816	·311	·208301	·373	·267078	·435	·327882	·497	·389699
·186	·100774	·249	·152680	·312	·209227	·374	·268045	·436	·328874	·498	·390699
·187	·101553	·250	·153546	·313	·210154	·375	·269013	·437	·329866	·499	·391699
·188	·102334	·251	·154412	·314	·211082	·376	·269982	·438	·330858	·500	·392699
·189	·103116	·252	·155280								

1226. **Problem** XIII. *To find the area of an ellipsis.*

Rule. Multiply the longest and shortest diameter together, and their product by ·7854, which will give the area required. This rule is founded on Theorem 3. Cor. 2. in Conic Sections. (1098, 1100.)

Example. Required the area of an ellipse whose two axes are 70 and 50.

$$\text{Here } 70 \times 50 \times {\cdot}7854 = 2748{\cdot}9.$$

1227. **Problem** XIV. *To find the area of any elliptic segment.*

Rule. Find the area of a circular segment having the same height and the same vertical axis or diameter; then, as the said vertical axis is to the other axis (parallel to the base of the segment), so is the area of the circular segment first found to the area of the elliptic segment sought. This rule is founded on the theorem alluded to in the previous problem. Or, divide the height of the segment by the vertical axis of the ellipse; and find in the table of circular segments appended to Prob. 12. (1224.) the circular segment which has the above quotient for its versed sine; then multiply together this segment and the two axes of the ellipse for the area.

Example. Required the area of an elliptic segment whose height is 20, the vertical axis being 70, and the parallel axis 50.

Here $20 \div 70 = {\cdot}2857142$, the quotient or versed sine to which in the table answers the segment ·285714.

Then $\cdot 285714 \times 70 \times 50 = 648{\cdot}342$, the area required.

1228. **Problem** XV. *To find the area of a parabola or its segment.*

Rule. Multiply the base by the perpendicular height, and take two thirds of the product for the area. This rule is founded on the properties of the curve already described in conic sections, by which it is known that every parabola is $\frac{2}{3}$ of its circumscribing parallelogram. (See 1097.)

Example. Required the area of a parabola whose height is 2 and its base 12.

Here $2 \times 12 = 24$, and $\frac{2}{3}$ of $24 = 16$ is the area required.

MENSURATION OF SOLIDS.

1229. The measure of every solid body is the capacity or content of that body, considered under the threefold dimensions of length, breadth, and thickness, and the measure of a solid is called its solidity, capacity, or content. Solids are measured by units which are cubes, whose sides are inches, feet, yards, &c. Whence the solidity of a body is said to be of so many cubic inches, feet, yards, &c. as will occupy its capacity or space, or another of equal magnitude.

1230. The smallest solid measure in use with the architect is the cubic inch, from which other cubes are taken by cubing the linear proportions, thus, —

1728 cubic inches = 1 cubic foot;
27 cubic feet = 1 cubic yard.

1231. **Problem** I. *To find the superficies of a prism.*

Multiply the perimeter of one end of the prism by its height, and the product will be the surface of its sides. To this, if wanted, add the area of the two ends of the prism. Or, compute the areas of the sides and ends separately, and add them together.

Example 1. Required the surface of a cube whose sides are 20 feet.

Here we have six sides; therefore $20 \times 20 \times 6 = 2400$ feet, the area required.

Example 2. Required the surface of a triangular prism whose length is 20 feet and each side of its end or base 18 inches.

Here we have, for the area of the base,

$1{\cdot}5^2 - {\cdot}75^2 = (2{\cdot}25 - {\cdot}5625 =)\ 1{\cdot}6875^2$ for the perpendicular of triangle of base;

and $\sqrt{1{\cdot}6875} = 1{\cdot}299$, which multiplied by $1{\cdot}5 = 1{\cdot}948$ gives the area of the two bases;

then, $3 \times 20 \times 1{\cdot}5 + 1{\cdot}948 = 91{\cdot}948$ is the area required.

Example 3. Required the convex surface of a round prism or cylinder whose length is 20 feet and the diameter of whose base is 2 feet.

Here, $2 \times 3{\cdot}1416 = 6{\cdot}2832$,

and $3{\cdot}1416 \times 20 = 125{\cdot}664$, the convex surface required.

1232. **Problem** II. *To find the surface of a pyramid or cone.*

Rule. Multiply the perimeter of the base by the length of the slant side, and half the product will be the surface of the sides or the sum of the areas of all the sides, or of the areas of the triangles whereof it consists. To this sum add the area of the end or base.

Example 1. Required the surface of the slant sides of a triangular pyramid whose slant height is 20 feet and each side of the base 3 feet.

Here, 20×3 (the perimeter) $\times 3 \div 2 = 90$ feet, the surface required.

Example 2. Required the convex surface of a cone or circular pyramid whose slant height is 50 feet and the diameter of its base 8½ feet.

Here, 8·5 × 3·1416 × 50 ÷ 2 = 667·5, the convex surface required.

1233. PROBLEM III. *To find the surface of the frustum of a pyramid or cone, being the lower part where the top is cut off by a plane parallel to the base.*

Rule. Add together the perimeters of the two ends and multiply their sum by the slant height. One half of the product is the surface sought. This is manifest, because the sides of the solid are trapezoids, having the opposite sides parallel.

Example 1. Required the surface of the frustum of a square pyramid whose slant height is 10 feet, each side of the base being 3 feet 4 inches and each side of the top 2 feet 2 inches.

Here, 3 feet 4 inches × 4 = 13 feet 4 inches, and 2 feet 2 inches × 4 = 8 feet 8 inches; and 13 feet 4 inches + 8 feet 8 inches = 22. Then 22 ÷ 2 × 10 = 110 feet, the surface required.

Example 2. Required the convex surface of the frustum of a cone whose slant height is 12½ feet and the circumference of the two ends 6 and 8·4 feet.

Here, 6 + 8·4 = 14·4; and 14·4 × 12·5 ÷ 2 = 180 ÷ 2 = 90, the convex surface required.

1234. PROBLEM IV. *To find the solid content of any prism or cylinder.*

Rule. Find the area of the base according to its figure, and multiply it by the length of the prism or cylinder for the solid content. This rule is founded on Prop. 99. (Geometry, 980.). Let the rectangular parallelopipedon be the solid to be measured, the small cube P (*fig.* 518.) being the measuring unit, its side being 1 inch, 1 foot, &c. Let also the length and breadth of the base ABCD, and also let the height AH, be divided into spaces equal to the side of the base of the cube P; for instance, here, in the length 3 and in the breadth 2, making 3 times 2 or 6 squares in the base AC each equal to the base of the cube P. It is manifest that the parallelopipedon will contain the cube P as many times as the base AC contains the base of the cube, repeated as often as the height AH contains the height of the cube. Or, in other words, the contents of a parallelopipedon is found by multiplying the area of the base by the altitude of the solid. And because all prisms and cylinders are equal to parallelopipedons of equal bases and altitudes, the rule is general for all such solids whatever the figure of their base.

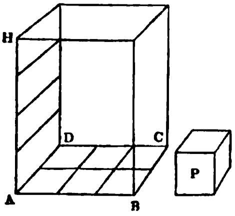


Fig. 518.

Example 1. Required the solid content of a cube whose side is 24 inches.

Here, 24 × 24 × 24 = 13824 cubic inches.

Example 2. Required the solidity of a triangular prism whose length is 10 feet and the three sides of its triangular end are 3, 4, and 5 feet.

Here, because (Prop. 32. Geometry, 907.) $3^2 + 4^2 = 5^2$, it follows that the angle contained by the sides 3 and 4 is a right angle. Therefore $\frac{3 \times 4}{2} \times 10 = 60$ cubic feet, the content required.

Example 3. Required the content of a cylinder whose length is 20 feet and its diameter 5 feet 6 inches.

Here, 5·5 × 5·5 × ·7854 = 23·75835, area of base;
and 23·75835 × 20 = 47·5167, content of cylinder required.

1235. PROBLEM V. *To find the content of any pyramid or cone.*

Rule. Find the area of the base and multiply that area by the perpendicular height. One third of the product is the content. This rule is founded on Prop. 110. (Geometry, 991.)

Example 1. Required the solidity of the square pyramid, the sides of whose base are 30, and its perpendicular height 25.

Here, $\frac{30 \times 30}{3} \times 25 = 7500$, content required.

Example 2. Required the content of a triangular pyramid whose perpendicular height is 30 and each side of the base 3.

Here, $\frac{3+3+3}{2} = \frac{9}{2} = 4{\cdot}5$, half sum of the sides;

and 4·5 − 3 = 1·5, one of the three equal remainders. (See Trigonometry, 1052.)

but $\sqrt{4{\cdot}5 \times 1{\cdot}5 \times 1{\cdot}5 \times 1{\cdot}5} \times 30 \div 3 = 3{\cdot}897117 \times 10$, or 38·97117, the solidity required.

Example 3. Required the content of a pentagonal pyramid whose height is 12 feet and each side of its base 2 feet.

Here, 1·7204774 (tabular area, Prob. 6. 1218.) × 4 (square of side) = 6·8819096 area of base;

Then $\frac{6{\cdot}68819096}{3} = 27{\cdot}5276384$, content required.

Example 4. Required the content of a cone whose height is 10½ feet and the circumference of its base 9 feet.

Here, ·07958 (Prob. 9. 1221.) × 81 = 6·44598 area of base,

And 3·5 being ⅓ of 10½ feet, 6·44598 × 3·5 = 22·56093 is the content required.

1236. Problem VI. *To find the solidity of the frustum of a cone or pyramid.*

Add together the areas of the ends and the mean proportional between them. Then taking one third of that sum for a mean area and multiplying it by the perpendicular height or length of the frustum, we shall have its content. This rule depends upon Prop. 110. (Geometry, 991.).

It may be otherwise expressed when the ends of the frustum are circles or regular polygons. In respect of the last, square one side of each polygon, and also multiply one side by the other; add the three products together, and multiply their sum by the tabular area for the polygon. Take one third of the product for the mean area, which multiply by the length, and we have the product required. When the case of the frustum of a cone is to be treated, the ends being circles, square the diameter or the circumference at each end, and multiply the same two dimensions together. Take the sum of the three products, and multiply it by the proper tabular number, that is, by ·7854, when the diameters are used, and ·07958 when the circumferences are used, and, taking one third of the product, multiply it by the length for the content required.

Example 1. Required the content of the frustum of a pyramid the sides of whose greater ends are 15 inches, and those of the lesser ends 6 inches, and its altitude 24 feet.

Here, ·5 × ·5 = ·25, area of the lesser end,

and 1·25 × 1·25 = 1·5625, area of the greater end:

The mean proportional therefore $\sqrt{\cdot25 \times 1\cdot5625} = \cdot625$.

Again, $\frac{\cdot25+\cdot625+1\cdot5625}{8} = \frac{2\cdot4375}{3} = \cdot8125$, mean area,

and ·8125 × 24 (altitude) = 19·5 feet, content required.

Example 2. Required the content of a conic frustum whose altitude is 18 feet, its greatest diameter 8, and its least diameter 4.

Here, 64 (area gr. diam.) + 16 (less. diam.) + (8 × 4) = 112, sum of the products;

and $\frac{\cdot7854 \times 112 \times 18}{3} = 527\cdot7888$, content required.

Example 3. Required the content of a pentagonal frustum whose height is 5 feet, each side of the base 18 inches, and each side of the upper end 6 inches.

Here, $1\cdot5^2 + 1\cdot5^2 + (1\cdot5 \times \cdot5) = 2\cdot5625$, sum of the products;

but, $\frac{1\cdot7204774 \text{ (tab. area)} \times 2\cdot5625 \text{ (sum of products)} \times 5}{3} = 9\cdot31925$, content required.

1237. Problem VII. *To find the surface of a sphere or any segment.*

Rule 1. Multiply the circumference of the sphere by its diameter, and the product will be the surface thereof. This and the rules in the following problems depend on Props. 113. and 114. (Geometry, 994, 995.), to which the reader is referred.

Rule 2. Square the diameter, and multiply that square by 3·1416 for the surface.

Rule 3. Square the circumference, then either multiply that square by the decimal ·3183, or divide it by 3·1416 for the surface.

Remark. For the surface of a segment or frustum, multiply the whole circumference of the sphere by the height of the part required.

Example 1. Required the convex superficies of a sphere whose diameter is 7 and circumference 22.

Here, 22 × 7 = 154, the superficies required.

Example 2. Required the superficies of a sphere whose diameter is 24 inches.

Here, 24 × 24 × 3·1416 = 1809·5616 is the superficies required.

Example 3. Required the convex superficies of a segment of a sphere whose axis is 42 inches and the height of the segment 9 inches.

Here, 1 : 3·1416 :: 42 : 131·9472, the circumference of the sphere;

but 131·9472 × 9 = 1187·5248, the superficies required.

Example 4. Required the convex surface of a spherical zone whose breadth or height is 2 feet and which forms part of a sphere whose diameter is 12½ feet.

Here, 1 : 3·1416 :: 12·5 : 39·27, the circumference of the sphere whereof the zone is a part;

and 39·27 × 2 = 78·54, the area required.

1238. Problem VIII. *To find the solidity of a sphere or globe.*

Rule 1. Multiply the surface by the diameter, and take one sixth of the product for the content.

Rule 2. Take the cube of the diameter and multiply it by the decimal ·5236 for the content.

Example. Required the content of a sphere whose axis is 12.

Here 12 × 12 × 12 × ·5236 = 904·7808, content required.

1239. **Problem IX.** *To find the solidity of a spherical segment.*

Rule 1. From thrice the diameter of the sphere subtract double the height of the segment, and multiply the remainder by the square of the height. This product multiplied by ·5236 will give the content.

Rule 2. To thrice the square of the radius add the square of its height, multiply the sum thus found by the height, and the product thereof by ·5236 for the content.

Example 1. Required the solidity of a segment of a sphere whose height is 9, the diameter of its base being 20.

Here, 3 times the square of the radius of the base $=300$;
and the square of its height $=81$, and $300+81=381$;
but $381 \times 9=3429$, which multiplied by $\cdot5236=1795\cdot4244$, the solidity required.

Example 2. Required the solidity of a spherical segment whose height is 2 feet and the diameter of the sphere 8 feet.

Here, $8 \times 3-4=20$, which multiplied by $4=80$;
and $80 \times \cdot5236=41\cdot888$, the solidity required.

It is manifest that the difference between two segments in which the zone of a sphere is included will give the solidity of the zone. That is, where for instance the zone is included in a segment lying above the diameter, first consider the whole as the segment of a sphere terminated by the vertex and find its solidity; from which subtract the upper part or segment between the upper surface of the zone and the vertex of the sphere, and the difference is the solidity of the zone.

The general rule to find the solidity of a frustum or zone of a sphere is: to the sum of the squares of the radii of the two ends add one third of the square of their distance, or the breadth of the zone, and this sum multiplied by the said breadth, and that product again by 1·5708, is the solidity.

Sect. VIII.

MECHANICS AND STATICS.

1240. It is our intention in this section to address ourselves to the consideration of mechanics and statics as applicable more immediately to architecture. The former is the science of forces, and the effects they produce when applied to machines in the motion of bodies. The latter is the science of weight, especially when considered in a state of equilibrium.

1241. The centre of motion is a fixed point about which a body moves, the axis being the fixed line about which it moves.

1242. The centre of gravity is a certain point, upon which a body being freely suspended, it will rest in any position.

1243. So that weight and power, when opposed to each other, signify the body to be moved and the body that moves it, or the patient and agent. The power is the agent which moves or endeavours to move the patient or weight, whilst by the word equilibrium is meant an equality of action or force between two or more powers or weights acting against each other, and which by destroying each other's effects cause it to remain at rest.

PARALLELOGRAM OF FORCES.

1244. If a body D suspended by a thread is drawn out of its vertical direction by an horizontal thread DE (*fig.* 519.), such power neither increases nor diminishes the effort

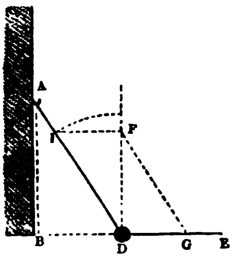


Fig. 519.

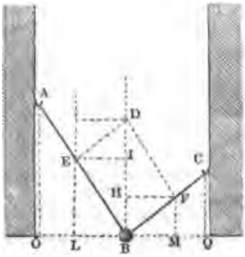


Fig. 520.

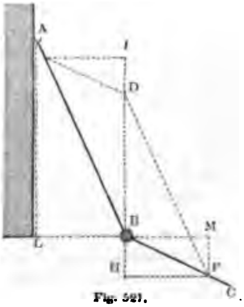


Fig. 521.

of the weight of the body; but it may be easily imagined that the first thread, by being in the direction AD, will, besides the weight itself, have to sustain the effort of the power that draws it out of the vertical AB.

1245. If the direction of the horizontal force be prolonged till it meets the vertical, which would be in the first thread if it were not drawn away by the second, we shall have triangle ADB, whose sides will express the proportion of the weight to the forces of the two threads in the case of equilibrium being established; that is, supposing AB to express the weight, AD will express the effort of the thread attached to the point A, and BD that of the horizontal power which pulls the body away from the vertical AB.

1246. These different forces may also be found by transferring to the vertical DH (*fig.* 520.) any length of line DF to represent the weight of the body. If from the point F the parallels FI, FG be drawn in the direction of the threads, their forces will be indicated by the lines ID, DG, so that the three sides of the triangle DGF, similar to the triangle ADB, will express the proportion of the weight to the two forces applied to the threads.

1247. Suppose the weight to be 30 lbs.: if from a scale of equal parts we set up 30 of those parts from D to F (*fig.* 519.), we shall find DG equal to 21, or the pounds of force of the horizontal line DE, and 35 for the oblique power ID.

1248. If the weight, instead of 30 lbs., were 100, we should find the value of the forces DG and ID by the proportions of 30 : 21 :: 100 : x, where x expresses the force DG. The value resulting from this proportion is $x = \frac{21 \times 100}{30} = 70$. The second proportion 30 : 35 :: 100 : y, where y represents the effort ID, whose value will be $y = \frac{35 \times 100}{30} = 116 \cdot 666$.

1249. If the angle ADH formed by AD and DH be known, the same results may be obtained by taking DF for the radius, in which case IF = DG becomes the tangent, in this instance, of 35 degrees, and ID the secant; whence

DF : DI : IF :: radius : tang. 35 : sec. 35.

If ID be taken for the radius, we have

ID : IF : FD :: radius : tang. 35 : sin. 35.

1250. We have here to observe, that in conducting the operation above mentioned a figure DIFG has been formed, which is called the parallelogram of the forces, because the diagonal DF always expresses a compounded force, which will place in equilibrio the two others FI, FG, represented by the two contiguous sides IF, FG.

1251. Instead of two forces which draw, we may suppose two others which act by pushing from E to D (*fig.* 522.) and from A to D. If we take the vertical DF to express the weight, and we draw as before the parallels FG and FI in the direction of the forces, the sides GD and DI of the parallelogram DGFI (*fig.* 519.) will express the forces with which the powers act relatively to DF to support the body: thus FI = GD the weight and two powers which support it will, in case of equilibrium, be represented by the three sides of a rectangular triangle DFI; so that if the weight be designated by H, the power which pushes from G to D by E, and that which acts from I to D by P, we shall have the proportion H : E : P :: DF : FI : ID, wherein, if we take DF for radius, it will be as radius is to the tangent of the angle FDI and to its secant. As a body in suspension is drawn away from the vertical line in which it hangs by a power higher than the body (*fig.* 520.), it follows that the oblique forces AB and BC each support, independent of any lateral efforts, a part of the weight of the body. In order to find the proportion of these parts to the total weight, take any distance BD on a vertical raised from the centre of the body B to express the weight, and complete the parallelogram DEBF, whose sides EB, BF will express the oblique forces of the powers A and C. These lines, being considered as the diagonals of the rectangular parallelograms LEIB, BHFM, may each be resolved into two forces, whereof one of them, vertical, sustains the body, and the other, horizontal, draws it away from the verticals AO, CQ. Hence IB will express the vertical force, or that part of the weight sustained by the power EB, and HB that sustained by the other power BF: as these two forces act in the same direction, when added together their sum will represent the weight DB. In short, IB being equal to HD, it follows that BH + BI = BI + ID.

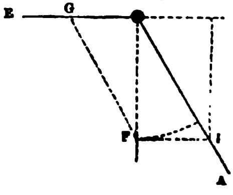


Fig. 522.

1252. As to the horizontal forces indicated by the lines LB and BM, as they are equal and opposite they destroy one another.

1253. It follows, from what has been said, that all oblique forces may be resolved into two others, one of which shall be vertical and the other horizontal, by taking their direction for the diagonal of a rectangular parallelogram.

1254. In respect of their ratio and value, those may be easily found by means of a scale if the diagram be drawn with accuracy; or by trigonometry, if we know the angles

ABD, DBC, which AB and BC form with the vertical BD, by taking successively for radius the diagonals BD, BE, and BF.

1255. In the accompanying diagram, the weight, instead of being suspended by strings acting by tension, is sustained by forces which are supposed to act by pushing. But as this arrangement makes no alteration in the system of forces, we may apply to this figure all that has been said with respect to the preceding one. The only difference is, that the parallelogram of the forces is below the weight instead of being above it. Thus ID + IB = BD expresses the sum of the vertical forces which support the weight, and MB and BL the horizontal forces which counteract each other.

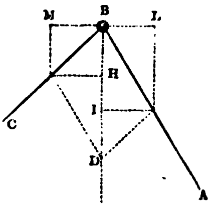


Fig. 523.

1256. In the two preceding figures the direction of the forces which act by tension or compression in supporting the weight form an acute angle. In those represented in *fig.* 521. and the figure at the side (524.), these directions make an obtuse angle; whence it follows that in *fig.* 521. the force C which draws the weight out of the vertical AG, instead of tending to support the weight B, increases its effect by its tendency to act in the same direction. In order to ascertain the amount of this effect upon BD in *figs.* 521. and 524., which represents the vertical action of the weight, describe the parallelogram BADF, for the purpose of determining the oblique forces BA, BF, and then take these sides for the diagonals of the two rectangles LAIB, BHFM, whose sides BI, BH will express the vertical forces, and LB, BM the horizontal ones.

1257. It must be observed that in *fig.* 521. the force AB acting upwards renders its vertical effect greater than the weight of a quantity ID, which serves as a compensation to the part BH, that the other force BF adds to the weight by drawing downwards. Similarly, the vertical effect of the force BE (*fig.* 524.) exceeds the expression BD of the weight by a quantity DI, to counterpoise the effect BH of the other power BF, which acts downwards; so that in both cases we have BD only for the vertical effect of the weight. As to the horizontal effects LB and BM, they being equal and in opposite directions in both figures, they counteract each other.

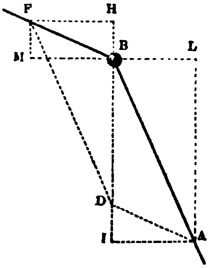


Fig. 524.

1258. For the same reason that a force can be resolved into two others, those two others may be resolved into one, by making that *one* the diagonal of a parallelogram whose forces are represented by two contiguous sides. It is clear, then, that whatever the number of forces which affect any point, they may be reduced into a single one. It is only necessary to discover the results of the forces two by two and to combine these results similarly two by two, till we come to the principal ones, which may be ultimately reduced to one, as we have seen above. By such a process we shall find that PY (*fig.* 525.) is the result of the forces PA, PB, PC, PD, which affect the point P.

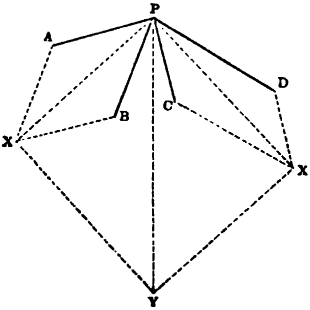


Fig. 525.

1259. This method of resolving forces is often of great utility in the science of building, for the purpose of providing a force to resist several others acting in different directions but meeting in one point.

OF THE PROPERTIES OF THE LEVER.

1260. The *lever* is an inflexible rod, bar, or beam serving to raise weights, whilst it is supported at a point by a *fulcrum*, or prop, which is the centre of motion. To render the demonstrations relative to it easier and simpler, it is supposed to be void of gravity or weight. The different positions in which the power applied to it, and the weight to be affected, may be applied in respect of the fulcrum, have given rise to the distinction of three sorts of levers.

I. That represented in *fig.* 526., in which the fulcrum O is between the power applied P and the weight Q.

II. That represented in *fig.* 527., in which the weight Q is placed between the fulcrum

O and the power P, wherein it is to be remarked that the weight and the power act in contrary directions.

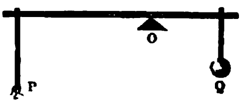


Fig. 526.

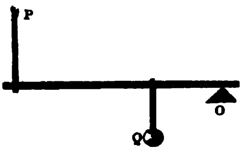


Fig. 527.

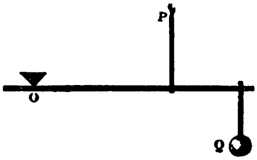


Fig. 528.

III. That represented in *fig.* 528., wherein the power P is placed between the weight and the fulcrum, in which case the power and the weight act in contrary directions.

1261. In considering the fulcrum of these three sorts of levers as a third species of power introduced for creating an equilibrium between the others, we must notice, 1st, That in which the directions of the weight and of the powers concur in the point R (*fig.* 529.). 2d, That in which they are parallel.

1262. In the first case, if from the point R (*figs.* 529. and 530.) we draw parallel to these directions Om Rn, the ratio of these three forces, that is, the power, the weight, and the fulcrum, will be as the three sides of the triangle OmR, or its equal OnR; thus we shall have $P : Q : R :: mR : Rn : OR$; and as the sides of a triangle are as the sines of their opposite angles, by taking OR as the radius we shall have

$$P : Q :: \sin. ORn : \sin. ORm.$$

And if from the point O two perpendiculars be let fall, Od Of, on the directions RQ, RP,

$$\text{Sin. } ORn : \sin. ORm :: Od : Of;$$

from which two proportions we obtain

$$P : Q :: Od : Of; \text{ whence } P \times Of = Q \times Od.$$

This last expression gives equal products, which are called the ***momenta, moments***, or quantities of motion of the force in respect of the fulcrum O. This property is the same for the straight as for the angular levers (*figs.* 529. and 530.). As this proportion exists, however large the angles mRO and ORn of the directions RQ, RP in respect to RO, it follows that when it becomes nothing, these directions become parallel without the proportion being changed; whence is derived the following general theorem, found in all works on mechanics: — *If two forces applied to a straight or angular lever are in equilibrio, they are in an inverse ratio to the perpendiculars let fall from the fulcrum on their lines of direction:* or in other words, *In order that two forces applied to a straight or angular lever may be in equilibrio, their momenta in respect of the fulcrum must be equal.*

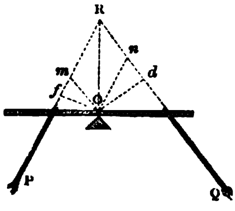


Fig. 529.

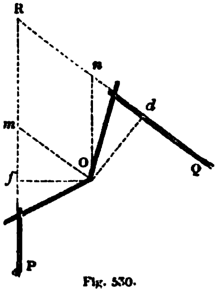


Fig. 530.

1263. Since, in order to place the lever in equilibrio, it is sufficient to obtain equal momenta, it follows that if we could go on increasing or diminishing the force, we might place it at any distance we please from the fulcrum, or load it without destroying the equilibrium. This results from the formula $P \times Of = Q \times Od$, whence we have $Of = \frac{Q \times Od}{P}$. Hence the distance Of is easily found, to which by applying the known force P, it may counterpoise the weight Q applied at the distance Od. In respect of the other points, we have only to know the perpendiculars Of and Od, for Oa and Ob, which are the arms of the real levers, are deduced from the triangles Ofb, Oda, to which they belong.

1264. Suppose two levers (*figs.* 531, 532.), whereof

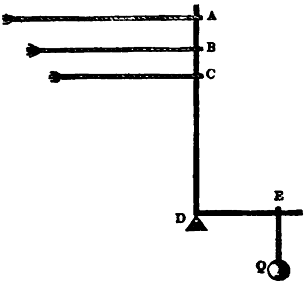


Fig. 532.

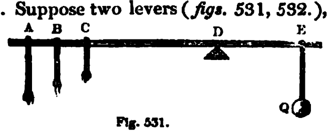


Fig. 531.

one is straight and the other angular, and that the weight Q is 100 pounds, the arm DE of the lever 6 feet; its momentum will be 600. Then if we wish to ascertain at what distance O*f* a weight of 60 pounds must be placed so that it may be in equilibrio with the first, we shall have

$$Of = \frac{Q \times Od}{P} = \frac{600}{60} = 10 \text{ feet, the distance sought.}$$

1265. Reciprocally, to find the effect of a force P placed at the point C of the other arm of the lever at a known distance from the fulcrum, and marked O*f*, in order to counterpoise Q placed at the distance O*f*, we have the formula $P = \frac{Q \times Od}{Of}$; and if we apply this formula to the numbers taken in the preceding example, the question will be, to find a force which placed at the distance of 10 feet from the fulcrum may be in equilibrio with a weight of 100 pounds at the end of the arm of a lever of 6 feet. We must in using the formula divide 600 by 10, and the quotient 60 will indicate the effect with which the force ought to act. If, instead of placing it in C, it is at B, 12 feet from the fulcrum, the force would be $\frac{600}{12}$, which gives 50; and lastly, if we have to place it at a point 15 feet from the fulcrum, the force would be $\frac{600}{15} = 40$. Thus, in changing the situation of the force to a point more or less distant from the fulcrum, we must divide the momentum of the weight which is to be supported by the distance from the fulcrum taken perpendicularly to its direction.

OF THE CENTRE OF GRAVITY.

1266. The centre of gravity of a body is a certain point within it on which the body, if freely suspended, will rest in any position; whilst in other positions it will descend to the lowest place to which it can get. Not only do whole bodies tend by their weight to assume a vertical direction, but also all the parts whereof they consist; so that if we suspend any body, whatever be its form, by means of a string, it will assume such a position that the thread produced to the internal part of the body will form an axis round which all the parts will remain in equilibrium. Every time that the point of suspension of a body is changed, the direction of the thread produced exhibits a new axis of equilibrium. But it is to be remarked, that all these axes intersect each other in the same point situate in the centre of the mass of the body, supposing it composed of homogeneous parts but sometimes out of the mass of the body, as in the case of bodies much curved, this point is the centre of gravity.

1267. It is therefore easy to perceive that for a body to be in a state of rest its centre of gravity must be supported by a vertical force equal to the resultant of all the forces that affect it, but acting in a contrary direction. So in *figs.* 520. and 523., the weight supported by the forces AB and BC which draw or push, will be equally supported by a vertical force represented by the diagonal DB of the parallelogram which expresses the resultant of the forces.

1268. An acquaintance with the method of finding centres of gravity is indispensable in estimating the resistances, strains, and degree of stability of any part of an edifice. There arise cases in which we may cast aside all consideration of the form of a body, especially too when it acts by weight, and suppose the whole figure collected in the centre of gravity. We may also, for the sake of simplifying operations, substitute a force for a weight.

OF THE CENTRE OF GRAVITY OF LINES.

1269. A straight line may be conceived to be composed of an infinite number of points, equally heavy, ranged in the same direction. After this definition, it is evident that if it be suspended by the middle, the two parts, being composed of the same number of equal points placed at equal distances from the point of suspension, will be necessarily in equilibrium; whence it follows that the centre of gravity of a right line is in the middle of its length.

1270. The points in a curve line not being in the same direction, the centre of its volume cannot be the same as its centre of gravity; that is to say, that a curve suspended by the middle cannot be supported in equilibrio but in two opposite situations; one when the branches of the curve are downwards, and the other when they are upwards, so that the curve may be in a vertical plane.

1271. If the curve is the arc of a circle ADB (*fig.* 533.), it is easy to see that from the uniformity of its curvature, its centre of gravity will be found in the right line DC drawn from the centre C to the middle D; moreover, if we draw the chord AB, the centre of gravity will be found between the points D and E.

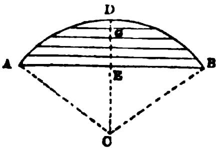


Fig. 533.

1272. Let us suppose that through all the points of the line DE parallels to the chord AB be drawn, terminated on each side by the curve; and let us imagine that each of these lines at its extremities bears corresponding points of the curve; then the line DE will be loaded with all these weights; and as the portions of the curve which answer to each parallel AB go on increasing as they approach D, the centre of gravity G will be nearer the point D than to the point E.

1273.* To determine the position of this point upon the radius CD which divides the arc into two equal parts, we must use the following proportion: the length of the arc ABD is to the chord AB, as the radius CD is to the fourth term x, whose value is $\frac{AB \times CD}{ABD}$. That is, in order to obtain upon the radius DC the distance CG of the centre of gravity from the centre of the arc of the circle, the chord AB must be multiplied by the radius CD and divided by the length of the arc ABD.

1274. When the circumference of the circle is entire, the axes of equilibrium being diameters, it is manifest that their intersection gives the centre of the curve as the centre of gravity. It is the same with all entire and symmetrical curves which have a centre, and with all combinations of right lines which form regular and symmetrical polygons.

OF THE CENTRE OF GRAVITY OF SURFACES.

1275. In order that a centre of gravity may be assigned to a surface, we must, as in the case of lines, imagine them to be material, that is, consisting of solid, homogeneous, and heavy particles.

1276. In all plane smooth surfaces, the centre of gravity is the same as that of the volume of space; thus the centre of gravity G (*figs.* 534, 535, 536.), of a square of a rectangle, or of a parallelogram, is determined by the intersections of its diagonals AD, BC.

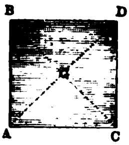


Fig. 534.

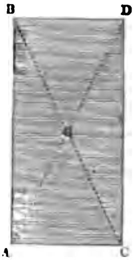


Fig. 535.

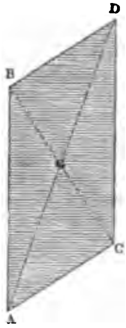


Fig. 536.

The centre of gravity of a regular polygon, composed of an equal or unequal number of sides, is the same as that of a circle within which it may be inscribed.

1277. In order to find the centre of gravity of any triangle, bisect each of the sides, and from the points of bisection draw lines to the opposite angles; the point of intersection with each other of these lines will be the centre of gravity sought; for in the supposition that the surface of the triangle is composed of lines parallel to its sides, the lines AE, BF, and CD (*fig.* 537.) will be the axes of equilibrium, whose intersection at G gives the centre of gravity. We shall moreover find that this point is at one third of the distance from the base of each of the axes; so that, in fact, it is only necessary to draw a line from the point of bisection of one of the sides to the opposite angle, and to divide it into three equal parts, whereof that nearest the base determines the centre of gravity of the triangle.

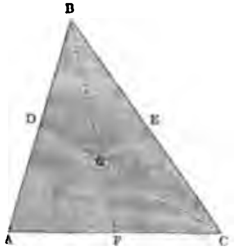


Fig. 537.

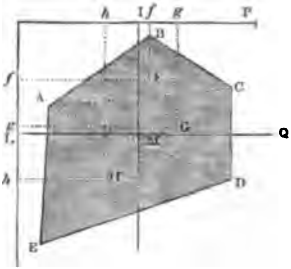


Fig. 538.

1278. To find the centre of gravity of any irregular rectilinear surface, such as the pentagon, *fig.* 538., let it be divided into the three triangles, AED, ABC, ADC (*fig.* 538.), and by the preceding rule determine their centres of gravity F, G, H. Then draw the two lines NO, OP, which form a right angle surrounding the polygon. Multiply the area of each triangle by the distance of its centre of gravity on the line ON, indicated by F*f*, G*g*, H*h*, and divide the sum of these products by the entire area of the pentagon, and this will give a mean distance through which an indefinite line IK parallel to ON is to be drawn. Conducting a similar operation in respect of the line OP, we obtain a new mean distance for drawing another line LO parallel to OP, which will intersect the first in the point M, the centre of gravity of the pentagon.

The centre of gravity of a sector of a circle AEBC (*fig.* 539.) must be upon the radius CE which divides the arc into two equal parts. To determine from the centre C, at what distance the point G is to be placed, we must multiply twice the radius CE by the chord AB, and divide the product by thrice the length of the arc AEB. The quotient is the distance CG from the centre C of the circle of the centre of gravity of the sector.

1279. To find the centre of gravity of the crown portion of an arch DAEBF (*fig.* 540.) comprised between two concentric axes, we must —

1. Find the centre of gravity of the greater sector AEBC, and that of the smaller one DFG.

2. Multiply the area of each of these sectors by the distance of their respective centres of gravity from the common centre C.

3. Subtract the smaller product from the greater, and divide the remainder by the area of DAEBF; the quotient will give the distance of the centre of gravity G from the centre C.

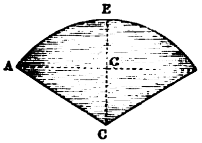


Fig. 539.

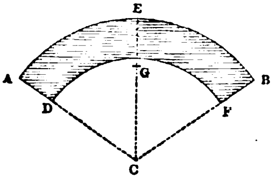


Fig. 540.

1280. To determine the centre of gravity of the segment AEB; subtract the product of the area of the triangle ABC (*fig.* 541.) multiplied by the distance of its centre of gravity from the centre C, from the product of the area of the sector, by the distance of its centre of gravity from the same point C, and divide the remainder by the area AEB; the quotient expresses the distance of the centre of gravity G of the segment from the centre C, which is to be set out on the radius, and which divides the segment into two equal parts.

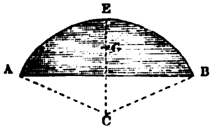


Fig. 541.

It would, from want of space, be inconvenient to give the strict demonstrations of the above rules; nor, indeed, is it absolutely necessary for the architectural student. Those who wish to pursue the subject *au fond*, will, of course, consult more abstruse works on the matter. We will merely observe, that whatever the figure whose centre of gravity is sought, it is only necessary to divide it into triangles, sectors, or segments, and proceed as above described for the pentagon, *fig.* 538.

OF THE CENTRE OF GRAVITY OF SOLIDS.

1281. It is supposed in the following considerations, that solids are composed of homogeneous particles whose weight in every part is uniform. They are here arranged under two heads, regular and irregular.

1282. Regular solids are considered as composed of elements of the same figure as their base, placed one upon the other, so that all their centres of gravity are in a vertical line, which we shall call the right axis. Thus parallelopipeds, prisms, cylinders, pyramids, cones, conoids, spheres, and spheroids have a right axis, whereon their centre of gravity is found.

1283. In parallelopipeds, prisms, cylinders, spheres, spheroids, the centre of gravity is in the middle of the right axis, because of the similarity and symmetry of their parts equally distant from that point.

1284. In pyramids and cones (*figs.* 542, 543.), which diminish gradually from the base to the apex, the centre of gravity is at the distance of one fourth of the axis from the base.

1285. In paraboloids, which diminish less on account of their curvature, the centre of gravity is at the height of one third the axis above the base.

To find the centre of a pyramid or of a truncated cone (*figs.* 542, 543.), we must first multiply the cube of the entire cone or pyramid by the distance of its centre of gravity from the vertex. 2. Subtract from this product that of the part MSR which is cut off, by the distance of its centre of gravity from the apex. 3. Divide this remainder by the cube of the truncated pyramid or cone; the quotient will be the distance of the centre of gravity G of the part of the truncated cone or pyramid from its apex.

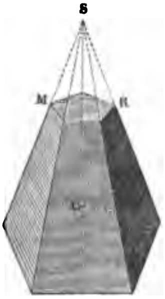


Fig. 542.

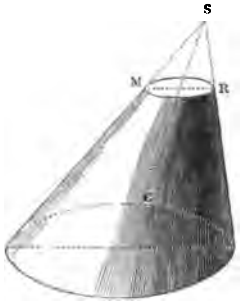


Fig. 543.

1286. The centre of gravity of a hemisphere is at the distance of three eighths of the radius from the centre.

1287. The centre of gravity of the segment of a sphere (*fig.* 544.) is found by the following proportion: as thrice the radius less the thickness of the segments is to the diameter less three quarters the thickness of the segment, so is that thickness to a fourth term which expresses the distance from the vertex to the centre of gravity, set off on the radius which serves as the axis.

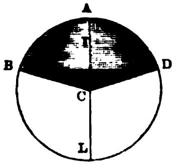


Fig. 544.

1288. Thus, making $r=$ the radius, $e=$ the thickness of the segment, and $x=$ the distance sought, we have, according to La Caille, —

$$3r-e : 2r-\frac{3e}{4} :: e : x, \text{ whence } x=\frac{8re-3e^2}{12r-4e}.$$

Suppose the radius to be 7 feet, the thickness of the segment 3 feet, we shall have —

$$x=\frac{8\times7\times3-3\times9}{12\times7-3\times4}, \text{ which gives } x=1+\tfrac{69}{72}=1+\tfrac{23}{24}, \text{ equal the distance}$$

of the centre of gravity from its vertex on the radius.

1289. To find the centre of gravity of the zone of a sphere (*fig.* 545.), the same sort of operation is gone through as for truncated cones and pyramids; that is, after having found the centre of gravity of the segment cut off, and that in which the zone is comprised, multiply the cube of each by the distance of its centre of gravity from the apex A, and subtracting the smaller from the larger product, divide the remainder by the cube of the zone. Thus, supposing, as before, the radius $AC=7$, the thickness of the zone $=2$, and that of the segment cut off $=1\frac{1}{2}$, we shall find the distance from the vertex of the centre of gravity of this last by the formula $x=\frac{8re-3ee}{4(3r-e)}$, which in this case gives $x=\frac{4\times2\times7\times1\frac{1}{2}-3\times2\frac{1}{4}}{4(21-1\frac{1}{2})}$; and pursuing the investigation, we have $x=\frac{103}{104}$, which will be the distance of the centre of gravity from the vertex A. That of the centre of gravity of the segment in which the zone is comprised will, according to the same formula, be $x=\frac{8\times7\times3\frac{1}{2}-3\times12\frac{1}{4}}{4(3\times7-3\frac{1}{2})}$, which gives $x=2+\frac{11}{40}$ for the distance of the centre of gravity from the same point A.

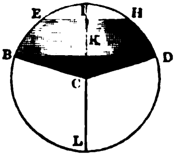


Fig. 545.

1290. The methods of finding the solidities of the bodies involved in the above investigation are to be found in the preceding section, on Mensuration.

OF THE CENTRE OF GRAVITY OF IRREGULAR SOLIDS.

1291. As all species of solids, whatever their form, are susceptible of division into pyramids, as we have seen in the preceding observations, it follows that their centres of gravity may be found by following out the instructions already given. Instead of two lines at right angles to each other, let us suppose two vertical planes NAC, CEF (*fig.* 546.), between which the solid G is placed. Carrying to each of those planes the momenta of their pyramids, that is, the products of their solidity, and the distances of their centres of gravity, divide the sum of these products for each plane by the whole solidity of the body, the quotient will express the distance of two other planes BKL, DHM, parallel to those first named. Their intersection will give a line IP, or an axis of equilibrium, upon which the centre of gravity of the solid will be found. To determine the point G, imagine a third plane NOF perpendicular to the preceding ones, that is, horizontal; upon which let the solid be supposed to stand. In respect of this plane let the momenta of the pyramids be found by also multiplying their solidity by the distance of their centres of gravity. Lastly, dividing the sum of these products by the solidity of the entire body, the quotient gives on the axis the distance PG of this third plane from the centre of gravity of the irregular solid.

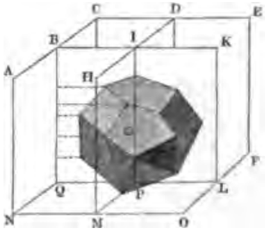


Fig. 546.

Mechanically, where two of the surfaces of a body are parallel, the mode of finding the centre of gravity is simple. Thus, if the body be hung up by any point A (*figs.* 547, 548.), and a plumb line AB be suspended from the same point, it will pass through

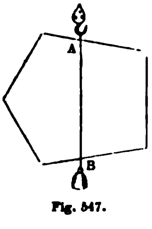


Fig. 547.

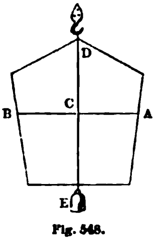


Fig. 548.

the centre of gravity, because that centre is not in the lowest point till it fall in the plumb line. Mark the line AB upon it; then hang the body up by any other point D, with a plumb line DE, which will also pass through the centre of gravity, for the same reason as before. Therefore the centre of gravity will be at C, where the lines cross each other.

1292. We have, perhaps, pursued this subject a little further than its practical utility in architecture renders necessary; but cases may occur in which the student will find our extended observations of service.

OF THE INCLINED PLANE.

1293. That a solid may remain in a perfect state of rest, the plane on which it stands must be perpendicular to the direction of its gravity; that is, level or horizontal, and the vertical let fall from its centre of gravity must not fall out of its base.

1294. When the plane is not horizontal, solids placed on it tend to slide down or to overturn.

1295. As the surfaces of bodies are more or less rough, when the direction of the centre of gravity does not fall without their base, they slide down a plane in proportion to their roughness and the plane's inclination.

1296. Thus a cube of hard freestone, whose surfaces are nicely wrought, does not slide down a plane whose inclination is less than thirty degrees; and with polished marbles the inclination is not more than fifteen degrees.

1297. When a solid is placed on an inclined plane, if the direction of the centre of gravity falls without its base, it overturns if its surfaces are right surfaces, and if its surface is convex it rolls down the plane.

1298. A body with plane surfaces may remain at rest after having once overturned if the surface upon which it falls is sufficiently extended to prevent its centre of gravity falling within the base, and the inclination be not so great as to allow of its sliding on.

1299. Solids whose surfaces are curved can only stand upon a perfectly horizontal plane, because one of the species, as the sphere, rests only on a point, and the other, as cylinders and cones, upon a line; so that for their continuing at rest, it is necessary that the vertical let fall from their centre of gravity should pass through the point of contact with and be perpendicular to the plane. Hence, the moment the plane ceases to be horizontal the direction of the centre of gravity falls out of the point or line of contact which serves as the base of the solid, and the body will begin to roll; and when the plane on which they thus roll is of any extent they roll with an accelerated velocity, equal to that which they would acquire in falling directly from the vertical height of the inclined plane from the point whence they first began to roll.

1300. To find the force which is necessary to support a convex body upon an inclined plane, we must consider the point of contact F (*figs.* 549, 550.) as the fulcrum of an angular lever, whose arms are expressed by the perpendiculars drawn from the fulcrum to the direction of the force CP and the weight CD, which in the case of *fig.* 549., where the force which draws the body is parallel to the plane,

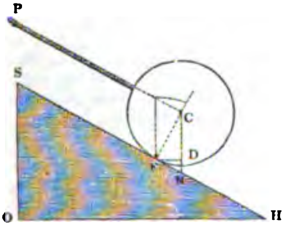


Fig. 549.

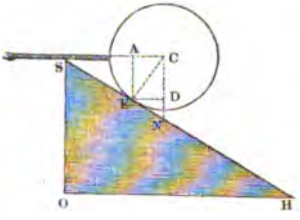


Fig. 550.

$$P : N :: FC : FD.$$

Now as the rectangular triangle CFD is always similar to the triangle OSH, which forms the plane inclined by the vertical SO and the horizontal line OH, the proportion will stand as follows: —

$$P : N :: OS : SH.$$

In the first case, to obtain an equilibrium, *the force must be to the weight of the body as the height* OS *of the inclined plane or to its length* SH.

1301. In the case where the force is horizontal (*fig.* 550.) we have, similarly, —

$$P : N :: FA : FD,$$

$$\text{and } P : N :: OS : OH.$$

In this last case, then, *the force must be to the weight of the solid in proportion to the height*

OS *of the inclined plane to its base* OH. In the first case the pressure of the solid on the plane is expressed by OH, and in the second by SH: hence we have —

P : N : F :: OS : SH : OH,
and P : N : F :: OS : SH : OH.

In the first case it must be observed, that the effect of the force being parallel to the inclined plane, it neither increases nor diminishes the pressure upon that plane; and this is the most favourable case for keeping a body in equilibrio on an inclined plane. In the second case, the direction forming an acute angle with the plane uselessly augments the load or weight. Whilst the direction of the force forms an obtuse angle with the inclination of the plane, by sustaining a portion of the weight, it diminishes the load on the plane, but requires a greater force.

1302. The force necessary to sustain upon an inclined plane a body whose base is formed by a plane surface depends, as we have already observed, on the roughness of the surfaces, as well of the inclined plane as of the base of the body; and it is only to be discovered by experiments.

1303. Of all the means that have been employed to estimate the value of the resistance, known under the name of friction, the simplest, and that which seems to give the truest results, is to consider the inclination of the plane upon which a body, the direction of whose centre of gravity does not fall out of the base, remains in equilibrio, as a horizontal plane; after which the degrees of inclination may begin to be reckoned, by which we find that a body which does not begin to slide till the plane's inclination exceeds 30 degrees, being placed on an inclined plane of 45, will not require a greater force to sustain it than a convex body of the same weight on an inclined plane of 15 degrees.

1304. All that has been said on the force necessary to retain a body upon an inclined plane, is applicable to solids supported by two planes, considering that the second acts as a force to counterpoise the first, in a direction perpendicular to the second plane.

1305. When the directions of three forces, PG, QG, GR, meet in the same point G (*fig.* 551.), it follows, from the preceding observations on the parallelogram of forces, that to be in equilibrium their proportion will be expressed by the three sides of a triangle formed by perpendiculars to their directions; whence it follows, that if through the centre of gravity G of a solid, supported by two planes or by some other point of its vertical direction, lines be drawn perpendicular to the directions of the forces, if equilibrium exist, so will the following proportion, viz. P : Q : R :: BA : BC : AC.

1306. Lastly, considering that in all sorts of triangles the sides will between each other be as the sines of their opposite angles, we shall have P : Q : R :: sin. BCA : sin. BAC : sin. ABC; and as the angle BCA is equal to the angle CAD, and CBA to BAE, we shall have P : Q : R :: sin. CAD : sin. BAC : sin. BAE; that is, that the weight is represented by the sine of the angle formed by the two inclined planes, and that the pressures upon each of these planes are reciprocally proportional to the sines of the angles which they form with the horizon.

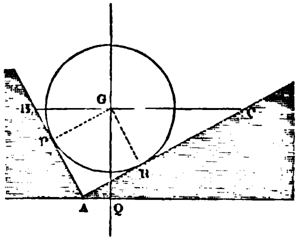


Fig. 551.

THE WHEEL AND AXLE.

1307. The wheel and axle, sometimes called the axis in peritrochio, is a machine consisting of a cylinder C and a wheel B (*fig.* 552.) having the same axis, at the two extremities of which are pivots on which the wheel turns. The power is applied at the circumference of the wheel, generally in the direction of a tangent by means of a cord wrapped about the cylinder in order to overcome the resistance or elevate the weight. Here the cord by which the power P acts is applied at the circumference of the wheel, while that of the weight W is applied round the axle or another small wheel attached to the larger, and having the same axis or centre C. Thus BA is a lever moveable about the point C, the power P always acting at the distance BC, and the weight W at the distance CA. Therefore P : W :: CA : CB. That is, the weight and power will be in equilibrio when the power P is to the weight W reciprocally as the radii of the circles where they act, or as the radius of the axle CA, where the weight hangs, to the radius of the wheel CB, where the power acts; or, as before, P : W :: CA : CB.

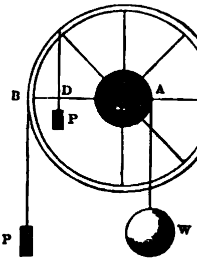


Fig. 552.

1308. If the wheel be put in motion, the spaces moved through being as the circumferences, or as the radii, the velocity of W will be to the velocity of P as CA to CB; that is, the weight is moved as much slower as it is heavier than the power. Hence, what is gained in power is lost in time; a property common to machines and engines of every class.

1309. If the power do not act at right angles to the radius CB, but obliquely, draw CD perpendicular to the direction of the power, then, from the nature of the lever, P : W :: CA : CD.

1310. It is to the mechanical power of the wheel and axle that belong all turning or wheel machines of different radii; thus, in the roller turning on the axis or spindle CE (*fig.* 553.) by the handle CBD, the power applied at B is to the weight W on the roller, as the radius of the roller is to the radius CB of the handle. The same rule applies to all cranes, capstans, windlasses, &c.; the power always being to the weight as is the radius or lever at which the weight acts to that at which the power acts; so that they are always in the reciprocal ratio of their velocities. To the same principle are referable the gimlet and auger for boring holes.

1311. The above observations imply that the cords sustaining the weights are of no sensible thickness. If they are of considerable thickness, or if there be several folds of them over one another on the roller or barrel, we must measure to the middle of the outermost rope for the radius of the roller, or to the radius of the roller must be added half the thickness of the cord where there is but one fold.

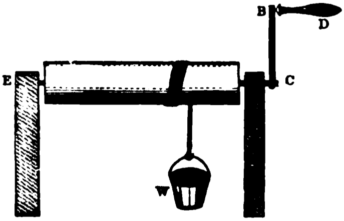


Fig. 553.

1312. The wheel and axle possesses considerable advantages in point of convenience over the simple lever. A weight can be raised but a little way by a simple lever, whereas by the continued turning of the wheel and axle a weight may be raised to any height and from any depth.

1313. By increasing the number of wheels, moreover, the power may be increased to any extent, making the less always turn greater wheels, by means of what is called *tooth and pinion* work, wherein the teeth of one circumference work in the rounds or pinions of another to turn the wheel. In case, here, of an equilibrium, the power is to the weight as the continual product of the radii of all the axles to that of all the wheels. So if the power P (*fig.* 554.) turn the wheel Q, and this turn the small wheel or axle R, and this turn the wheel S, and this turn the axle T, and this turn the wheel V, and this turn the axle X, which raises the weight W; then P : W :: CB . DE . FG : AC . BD . EF. And in the same proportion is the velocity of W slower than that of P. Thus, if each wheel be to its axle as 10 to 1, then P : W :: 1^3 : 10^3, or as 1 to 1000. Hence a power of one pound will balance a weight of 1000 pounds; but when put in motion, the power will move 1000 times faster than the weight.

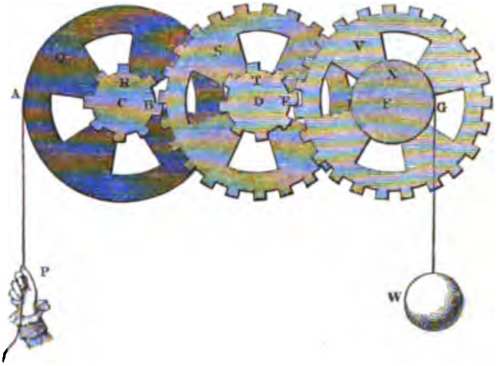


Fig. 554.

1314. We do not think it necessary to give examples of the different machines for raising weights used in the construction of buildings: they are not many, and will be hereafter named and described.

OF THE PULLEY.

1315. A pulley is a small wheel, usually made of wood or brass, turning about a metal axis, and enclosed in a frame, or case, called its *block*, which admits of a rope to pass freely over the circumference of the pulley, wherein there is usually a concave groove to prevent the rope slipping out of its place. The pulley is said to be fixed or moveable as its block is fixed or rises and falls with the weight. An assemblage of several pulleys is called a system of pulleys, of which some are in a fixed block and the rest in a moveable one.

1316. If a power sustain a weight by means of a fixed pulley. the power and weight are equal. For if through the centre C (*fig. 555.*) of the pulley we draw the horizontal diameter AB; then will AB represent a lever of the first kind, its prop being the fixed centre C, from which the points A and B, where the power and weight act, being equally distant, the power P is consequently equal to the weight W.

1317. Hence, if the pulley be put in motion, the power P will descend as fast as the weight W ascends: so that the power is not increased by the use of the fixed pulley, even though the rope go over several of them. It is, nevertheless, of great service in the raising of weights, both by changing the direction of the force, for the convenience of acting, and by enabling a person to raise a weight to any height without moving from his place, and also by permitting a great number of persons to exert, at the same time, their force on the rope at P, which they could not do to the weight itself, as is evident in raising the weight, or *monkey*, as it is called, of a pile-driver, also on many other occasions.

1318. When a pulley is moveable the power necessary to sustain a weight is equal to the half of such weight. For in this case AB (*fig. 556.*) may be considered as a lever of the second kind, the weight being at C, the power acting at A, and the prop or fixed point at B. Then, because P : W :: CB : AB and CB = AB, we have $P = \frac{1}{2}W$ or $W = 2P$.

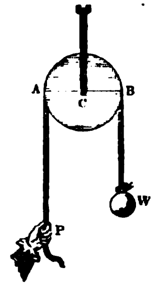


Fig. 555.

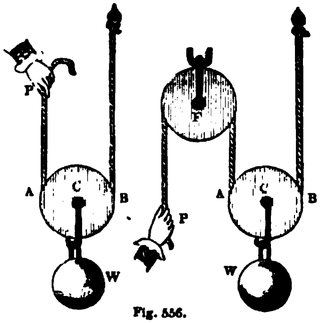


Fig. 556.

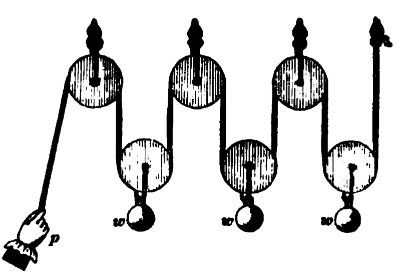


Fig. 557.

1319. From which it is manifest that when the pulley is put in motion the velocity of the power is double that of the weight, inasmuch as the point P descends twice as fast as the point C and the weight W rises. It is, moreover, evident that the fixed pulley F makes no difference in the point P, but merely changes the motion of it in an opposite direction.

1320. We may hence ascertain the effect of a combination or system of any number of fixed and moveable pulleys, and we shall thereby find that every cord going over a moveable pulley doubles the powers, for each end of the rope bears an equal share of the weight, whilst each rope fixed to a pulley only increases the power by unity. In *fig. 557.* $P = \frac{1}{6}W$, and in *fig. 558.*, $P = \frac{1}{2}w = \frac{w+w+w}{6}$.

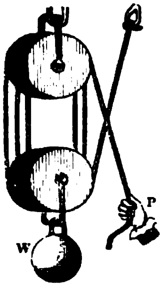


Fig. 558.

OF THE WEDGE.

1321. The wedge is a body in the form of a half rectangular prism, in practice usually of wood or metal. AF or BG (*fig. 559.*) is the breadth of its back, CE its height, CG, CB its sides, and its end, GBC, is the terminating surface of two equally inclined planes GCE, BCE.

1322. When a wedge is in equilibrio, the power acting on the back is to the force acting at right angles to either side as the breadth of the back AB (*fig. 560.*) is to the length of the side AC or BC. For three forces which sustain each other in equilibrio are as the corresponding sides of a triangle drawn perpendicular to the directions in which they act. But AB is perpendicular to the force

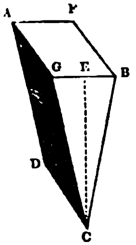


Fig. 559.

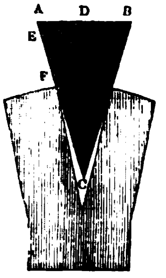


Fig. 560.

acting on the back to drive the wedge forward, and the sides AC, BC are perpendicular to the forces acting on them, the three forces are therefore as AB, AC, BC. Thus, the force on the back, its effect perpendicularly to AC, and its effect parallel to AB, are as the three lines AB, AC, and DC, which are perpendicular to them. Hence the thinner the wedge the greater its effect to split any body or to overcome a resistance against the sides of the wedge.

1323. We are, however, to recollect that the resistance or the forces in question are relative to one side only of the wedge; for if those against both sides are to be reckoned, we can take only half the back AD, or else we must take double the line AC or DC. In the wedge the friction is very great, and at least equal to the force to be overcome, inasmuch as it retains any position to which it is driven, whence the resistance is doubled by the friction. But on the other hand, the wedge has considerable advantage over all the other powers, because of the force of the blow with which the back is struck, a force vastly greater than the dead weight or pressure employed in other machines. On this account it is capable of producing effects vastly superior to those of any other power, such as splitting rocks, raising the largest and heaviest bodies by the simple blow of a mallet; objects which could never be accomplished by any simple pressure whereof in practice application could be made.

OF THE SCREW.

1324. The screw is a cord wound in a spiral direction round the periphery of a cylinder, and is therefore a species of inclined plane, whose length is to its height as the circumference of the cylinder is to the distance between two consecutive threads of the screw. It is one of the six mechanical powers used in pressing or squeezing bodies close, and is occasionally used in raising weights.

1325. The screw, then, being an inclined plane or half wedge, the force of a power applied in turning it round is to the force with which it presses upwards or downwards, without estimating friction, as the distance between two threads is to the circumference where the power is applied. For considering it as an inclined plane whose height is the distance between two threads, and its base the circumference of the screw; the force in the horizontal direction being to that in the vertical one as the lines perpendicular to them, namely, as the height of the plane or distance between two threads, is to the base of the plane or circumference of the screw; the power, therefore, is to the pressure as the distance of two threads is to the circumference. But in the application of the screw a handle or lever is used, by means whereof the gain in power is increased in the proportion of the radius of the screw to the radius of the power, that is, the length of the handle, or as their circumferences. Consequently the power is to the pressure as the distance of the threads is to the circumference described by the power. The screw being put in motion, the power is then to the weight which would keep it in equilibrio as the velocity of the latter is to that of the former; and hence their momenta are equal, and produced by multiplying each weight or power by its own velocity.

1326. Thus it is a general property of all the mechanical powers, that the momentum of a power is equal to that of the weight which would keep it in equilibrio, or that each of them is proportional to its velocity.

1327. From the foregoing observations, we may be easily led to compute the force exerted by any machine whose action is exerted through the means of the screw. In *fig.* 561., representing a press driven by a screw whose threads are each one quarter of an inch apart, let it be turned by a handle or lever 4 feet long from A to B. Then supposing the natural force of a man, by which he can lift, pull, or draw, to be 150 pounds, and that it be required to ascertain with what force the screw will press on the board at D when the man turns with his whole force the handle at A and B; we have AB, the diameter of the power, 4 feet or 48 inches; its circumference, therefore, 48 × 3·1416, or 150⅘ nearly; and the distance of the threads being one quarter of an inch, the power is to the pressure as 1 to 603⅕. But the power is equal to 150 pounds; therefore, as 1 : 603⅕::150 : 90480, and the pressure therefore at D is equal to a weight of 90480 pounds, independent of friction.

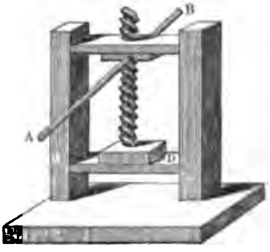


Fig. 561.

1328. In the endless screw AB (*fig.* 562.), turned by a handle AC of 20 inches radius, the threads of the screw are at a distance of half an inch; and the screw turns a toothed wheel E whose pinion L acts in turning upon another wheel F, and the pinion M of this last wheel acts upon a third wheel G, to the pinion or barrel whereof is hung the weight W. If we would know what weight can be raised through the means of this combination by a man working the handle C, supposing the diameters of the wheels to be 18 inches, and those of the pinions and barrel 2 inches, the teeth and pinions being all similar in size; we have 20 × 3·1416 × 2 = 125·664, the circumference of the power; and 125·664 to ½, or 251·328 to 1, is the force of the screw alone. Again, 18 : 2 or 9 : 1, being the proportion of the wheels to the pinions, and there being three of them, 9^3 : 1 or 729 : 1 is the power gained by the wheels.

1329. Consequently 251·328 × 729 to 1, or 183218$\frac{1}{8}$ to 1 nearly, is the ratio of the power to the weight arising from the joint advantage of the screw and the wheels. The power, however, is 150 pounds; therefore 150 × 183218$\frac{1}{8}$ or 27482716 pounds is the weight the man can sustain, equal to 12269 tons.

1330. It must be observed, that the power has to overcome not only the weight, but at the same time the friction undergone by the screw, which in some cases is so great as to be equal to the weight itself; for it is sometimes sufficient to sustain the weight when the power is taken off.

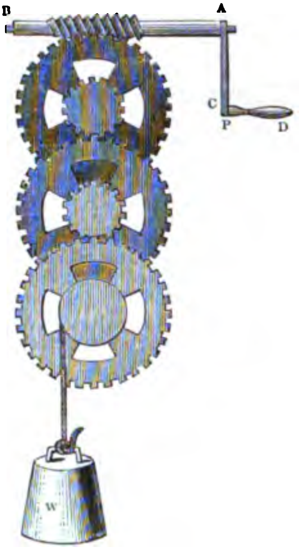


Fig. 562.

OF FRICTION.

1331. Though in a preceding page we have slightly touched on the effect of friction, it is to be kept in mind that the foregoing observations and rules have assumed the mechanical powers to be without weight and friction. This is far from the fact; and, however theoretically true all that has hitherto been advanced, very great allowances must be made in practice when power is applied to mechanical purposes, in which a great portion of their effect is lost by friction, inertia, &c. The word friction, properly meaning the act of one body rubbing on another, is in mechanics used to denote the degree of retardation or obstruction to motion which arises from one surface rubbing against another. A heavy body placed upon another is not in a state of equilibrium between all the forces which act upon it, otherwise it could be moved by the application of the smallest force in a direction parallel to the plane. This want of equilibrium results from unbalanced force occasioned by the friction on a level surface. Now if a new force of equal magnitude be applied to counterpoise such unbalanced force, the body will obey the smallest impulse in such direction, and the force thus employed will exactly measure the retarding force of friction. It has been well observed, that friction destroys, but never generates motion; being therein unlike gravity or the other forces, which, though they may retard motion in one direction, always accelerate it in the opposite. Thus the law of friction violates the law of continuity, and cannot be accurately expressed by any geometrical line, nor by any algebraic formula. The author (Playfair, *Outlines of Natural Philosophy*) just quoted, continues: "Though friction destroys motion and generates none, it is of essential use in mechanics. It is the cause of stability in the structure of machines, and it is necessary to the exertion of the force of animals. A nail or screw or a bolt could give no firmness to the parts of a machine, or of any other structure, without friction. Animals could not walk, or exert their force anyhow, without the support which it affords. Nothing could have any stability, but in the lowest possible situation; and an arch, which could sustain the greatest load when properly distributed, might be thrown down by the weight of a single ounce, if not placed with mathematical exactness at the very point which it ought to occupy."

1332. Many authors have applied themselves to the subject of friction, but the most satisfactory results have attended the investigations of the celebrated Coulomb in its application to practical mechanics; and it is to that author we are indebted for the few following succinct observations.

I. In the friction of wood upon wood in the direction of the fibres after remaining in contact for one or two minutes, the following mean results were obtained: —

Oak against oak - $\frac{1}{2{\cdot}34}$ = friction in parts of the weight.
Oak against fir - - $\frac{1}{1{\cdot}50}$ = ditto.
Fir against fir - - $\frac{1}{1{\cdot}78}$ = ditto.
Elm against elm - $\frac{1}{2{\cdot}18}$ = ditto.

When oak rubbed upon oak, and the surfaces in contact were reduced to the smallest possible dimensions, the friction was $\frac{1}{2{\cdot}36}$, $\frac{1}{2{\cdot}42}$, $\frac{1}{2{\cdot}40}$.

1333. When the friction was across the grain, or at right angles to the direction of the fibres, oak against oak was $\frac{1}{3\cdot76}$. The ratios above given are constant quantities, and not dependent upon the velocities, excepting in the case of elm, when the pressures are very small, for then the friction is sensibly increased by the velocity.

1334. (II.) Friction is found to increase with the time of contact. It was ascertained that when wood moved upon wood in the direction of the fibres, the friction gradually increased, and reached its maximum in 8 or 10 seconds. When across the grain of the wood, it took a longer time to reach its maximum.

1335. (III.) For illustration of the friction of metals upon metals after a certain time of rest, the subjoined experiments were made with two flat rulers of iron, 4 feet long and 2 inches wide, attached to the fixed plank of the apparatus used for the investigation. Four other rulers, two of iron and two of brass, 15 inches long and 18 lines wide, were also used. The angles of each of the rulers were rounded off, and the rubbing surfaces of the rulers were 45 square inches.

With iron upon iron and a pressure of 53 lbs., the friction in parts of the pressure was $\frac{1}{3\cdot5}$.
— — 453 lbs., — — $\frac{1}{3\cdot6}$.

With iron upon brass and a pressure of 52 lbs., the friction in parts of the pressure was $\frac{1}{4\cdot2}$.
— — 452 lbs., — — $\frac{1}{4\cdot1}$.

1336. In these experiments each set gives nearly the same result, though the second pressures are nearly nine times the first; from which we learn that, in metals, friction is independent of the extent of the rubbing surfaces. Coulomb, moreover, found that the friction is independent of the velocities. The ratio of 4 to 1 between the pressure of friction, in the case of iron moving upon brass, is only to be considered accurate when the surfaces are new and very large. When they are very small the ratio varies from 4 to 1 to 6 to 1; but this last ratio is not reached unless the friction has been continued more than an hour, when the iron and brass have taken the highest polish whereof they are susceptible, free of all scratches.

1337. IV. In the friction of oak upon oak, when greased with tallow, which was renewed at every experiment, some days were required for obtaining, when the surfaces were considerable, the maximum of friction or adhesion. It was nearly similar to that without grease, sometimes rather greater. For iron or copper with tallow, during rest, the increase is not so considerable as with oak. At first the friction was $\frac{1}{11}$ of the weight, besides a small force of a pound for every 30 square inches independent of the weight. The friction after some time changes to $\frac{1}{10}$ or $\frac{1}{8}$. Olive oil alters the condition of the friction to $\frac{1}{6}$, and old soft grease to about $\frac{1}{7}$.

1338. V. In the case of friction of bodies, oak upon oak for instance, in motion in the direction of its fibres, the friction was nearly constant in all degrees of velocity, though with large surfaces it appeared to increase with the velocities; but when the touching surfaces were very small compared with the pressures, the friction diminished or the velocities increased. For a pressure of 100 to 4000 pounds on a square foot, the friction is about $\frac{1}{9\cdot5}$, besides for each square foot a resistance of $1\frac{3}{4}$ pounds, exclusive of pressure increasing a little with the velocity, occasioned perhaps by a down on the surface. If the surface be very small the friction is lessened. When the narrow surface was cross-grained, the friction was invariably $\frac{1}{10}$. In the case of oak on fir, the friction was $\frac{1}{6\cdot3}$; of fir on fir, $\frac{1}{6}$; of elm on elm, $\frac{1}{10}$, but varying according to the extent of surface; for iron or copper on wood, $\frac{1}{13}$, which was at first doubled by increasing the velocity to a foot in a second, but on a continuance of the operation for some hours it again diminished. For iron on iron, $\frac{1}{3\cdot56}$; on copper, $\frac{1}{4\cdot15}$; after long attrition, $\frac{1}{6}$ in all velocities. Upon the whole, in the case of most machines, $\frac{1}{6}$ of the pressure may be considered a fair estimate of the friction.

1339. In the experiments to ascertain the friction of axles, Coulomb used a simple pulley, where the friction of the axis and that of the rigidity of the rope produce a joint resistance. With guaiacum moving upon iron, the friction was $\frac{1}{5\cdot4}$ or $\frac{1}{6\cdot4}$ of the weight in all velocities, exclusive of the rigidity of the rope; the mean was $\frac{1}{6\cdot1}$, or, with a small weight, a little greater. In the cases of axles of iron on copper, $\frac{1}{11}$ or $\frac{1}{11\cdot5}$ the velocity is small; the friction being always somewhat less than for plane surfaces. With grease, the friction was about $\frac{1}{7\cdot5}$. With an axis of green oak or elm, and a pulley of guaiacum, the friction with tallow was $\frac{1}{26}$; without, $\frac{1}{17}$; with a pulley of elm, the quantities in question became $\frac{1}{33}$ and $\frac{1}{20}$. An axis of box with a pulley of guaiacum gave $\frac{1}{23}$ and $\frac{1}{14}$; with an elm pulley, $\frac{1}{29}$ and $\frac{1}{20}$. An axis of iron and a pulley of guaiacum gave, with tallow, $\frac{1}{20}$. The velocity had but small effect on the rigidity of ropes, except in slightly increasing the resistance when the pressure was small.

1340. The friction and rigidity of ropes was supposed by Amontons and Desaguliers to vary as the diameter as the curvature and as the tension. By Coulomb the power of the diameter expressing the rigidity was found generally to be 1·7 or 1·8, never less than 1·4, and that a constant quantity must be supposed as added to the weight. Wet ropes, if small, are more flexible than such as are dry, and tarred ones stiffer by about one sixth, and in cold weather somewhat more. After rest, the stiffness of ropes increases. A rope of three strands, each having two yarns 12¼ lines in circumference, whose weight was 125 grains, being bent upon an axis 4 inches in diameter, required a constant force of one pound (French) and $\frac{1}{54\cdot3}$ of the weight to overcome its rigidity. The same rope tarred, required one fifth of a pound and one fiftieth of the weight. When the strands were of fine yarns, the circumference 20 lines, and the weight 347 grains, the rigidity was equal to half a pound and $\frac{1}{23\cdot1}$ of the weight to move it. With strands of 10 yarns, and a circumference of 28 lines, and a weight of 680 grains to 6 inches, the rigidity of the untarred rope was 2 lbs. and $\frac{1}{13\cdot33}$ of the weight, and the tarred rope of 3·3 lbs. and $\frac{1}{10\cdot34}$ of the weight. Experiments which confirmed the above were made on a roller moving on a horizontal plane, while a rope was coiled completely round it, whence an allowance must be made for the friction of the roller on the plane, which varies as its weight and inversely as its diameter. With a roller of guaiacum or lignum vitæ, 3·6 inches in diameter, moving on oak, it was $\frac{1}{100}$ of the weight; for a roller of elm, ⅜ more.

1341. This subject has, we conceive, been pursued as far as is necessary for the architect; seeing that his further investigation of it, should necessity arise, may be accomplished by reference to the works of Amontons, Bulfinger, Parent, Euler, Bossut, and Coulomb, upon whom we have drawn for the information here given. We shall therefore conclude these remarks by subjoining some of the practical results which experiments on animal power afford, extracted from the celebrated Dr. Thomas Young's *Natural Philosophy*, vol. ii.

1342. In comparing the values of the force of moving powers, it is usual to assume an unit, which is considered as the mean effect of the labour of an active man working to the greatest advantage; this on a moderate calculation will be found sufficient to raise 10 lbs. to the height of 10 feet in one second for 10 hours in a day; or 100 lbs. 1 foot in a second, that is 36,000 feet in a day, or 3,600,000 lbs. 1 foot in a day. The following exhibits a tabular view of the immediate force of men, without deduction for friction. Such a day's work is the measuring unit in the third column of the table.

Operative.	Force.	Continuance.	Day's Work.
A man weighing 133 lbs. French ascended 62 feet French by steps in 34 seconds, but was completely exhausted. *Amontons.* - - -	2·8	34 sec.	
A sawyer made 200 strokes of 18 French inches each in 145 seconds, with a force of 25 lbs. French. He could not have continued more than 3 minutes. *Amontons.* - - - - -	6·0	145 sec.	
A man can raise 60 French lbs. 1 French foot in 1 second for 8 hours a day. *Bernouilli.* -	0·69	8 hours	0·552
A man of ordinary strength can turn a winch with a force of 30 lbs., and with a velocity of 3½ feet in 1 second for 10 hours a day. *Desaguliers.* -	1·05	10 hours	1·05
Two men working at a windlass, with handles at right angles, can raise 70 lbs. more easily than 1 can raise 30 lbs. *Desaguliers.* - - - -	1·22	—	1·22
A man can exert a force of 40 lbs. for a whole day with the assistance of a fly, when the motion is pretty quick, at about 4 or 5 feet in a second. *Desaguliers.* But it appears doubtful whether the force is 40 or 20 lbs. - - - -	2·00	—	2·00
For a short time, a man may exert a force of 80 lbs. with a fly when the motion is pretty quick. *Desaguliers.* - - . - - - -	3·00	1 sec.	
A man going up stairs ascends 14 metres (35·43 feet) in 1 minute. *Coulomb.* - - - -	1·182	1 min.	

OPERATIVE.	Force.	Continuance.	Day's Work.
A man going up stairs for a day raises 205 kilogrammes (451·64 lbs. averd.) to the height of a kilometre (3280·91 feet). *Coulomb.* - -	—	—	0·412
With a spade a man does 19/20 as much as in ascending stairs. *Coulomb.* - - - -	—	—	0·391
With a winch a man does 5/8 as much as in ascending stairs. *Coulomb.* - - - -	—	—	0·258
A man carrying wood up stairs raises, together with his own weight, 109 kilogrammes (240·14 lbs. averd.) to 1 kilometre (3280·91 feet). *Coulomb.* - - - - - - -	—	—	0·219
A man weighing 150 French lbs. can ascend by stairs 3 French feet in a second for 15 or 20 seconds. *Coulomb.* - - - - -	5·22	20 sec.	
For half an hour 100 French pounds may be raised 1 foot French per second. *Coulomb.* - -	1·152	30 min.	
By Mr. Buchanan's comparison, the force exerted in turning a winch being assumed equal to the unit, the force in pumping will be - - -	0·61		
In ringing - - - - - - -	1·36		
In rowing - - - - - - -	1·43		

1343. Coulomb's maximum of effect is, when a man weighing 70 kilogrammes (154·21 lbs. avoirdupois), carries a weight of 53 (116·76 lbs. avoirdupois,) up stairs. But this appears too great a load.

1344. Porters carry from 200 to 300 lbs., at the rate of 3 miles an hour. Chairmen walk 4 miles an hour with a load of 150 lbs. each; and in Turkey there are found porters who, it is said, by stooping forwards, carry from 700 to 900 lbs. very low on their backs.

1345. The most advantageous weight for a man of common strength to carry horizontally, is 111 pounds; or, if he return unladen, 135. With wheelbarrows, men will do half as much more work, as with hods. *Coulomb.*

The following table exhibits the performance of men by machines.

OPERATIVE.	Force.	Continuance.	Day's Work.
A man raised by means of a rope and pulley 25 lbs. French, 220 French feet in 145 seconds. *Amontons.* - - - - - - -	0·436	145 sec.	
A man can raise by a good common pump 1 hogshead of water 10 feet high in a minute for a whole day. *Desaguliers.* - - - - -	0·875	—	0·875
By the mercurial pump, or another good pump, a man may raise a hogshead 18 or 20 feet in a minute for 1 or 2 minutes - - -	1·61	2 min.	
In pile driving, 55⅓ French lbs. were raised 1 French foot in 1 second, for 5 hours a day, by a rope drawn horizontally. *Coulomb.* - - -	0·64	5 hours	0·82
Robison says that a feeble old man raised 7 cubic feet of water 11¼ feet in 1 minute for 8 or 10 hours a day, by walking backwards and forwards on a lever - - - - -	0·837	9 hours	0·753
A young man, the last-named author says, weighing 135 lbs., and carrying 30 lbs., raised 9¼ cubic feet 11¼ feet high for 10 hours a day, without fatigue - - - - -	1·106	10 hours	1·106

1346. In respect of the force of horses, we do not think it necessary to do more than observe that the best way of applying their force is in an horizontal direction, that in which a man acts least to advantage. For instance, a man weighing 140 lbs., and drawing a boat along by means of a rope over his shoulders, cannot draw above 27 lbs.; whereas a horse employed for the same purpose can exert seven times that force.

1347. Generally, a horse can draw no more up a steep hill than three men can carry, that is, from 450 to 750 pounds; but a horse can draw 2000 pounds up a steep hill which is but short. The most disadvantageous mode of applying a horse's force is to make him carry or draw up hill; for if it be steep, he is not more than equal to three men, each of whom would climb up faster with a burden of 100 pounds weight than a horse that is loaded with 300 pounds. And this arises from the different construction of what may be called the two living machines.

1348. Desaguliers observes, that the best and most effectual action of a man is that exerted in rowing, in which he not only acts with more muscles at once for overcoming resistance than in any other application of his strength, but that, as he pulls backwards, his body assists by way of lever.

1349. There are cases in which the architect has to avail himself of the use of horse power; as, for instance, in pugmills for tempering mortar, and occasionally when the stones employed in a building may be more conveniently raised by such means. We therefore think it proper to observe, that, for effectually using the strength of the animal, the *track* or diameter of a walk for a horse should not be less than 25 to 30 feet.

1350. We close this section by observing, more for the curiosity of the thing than for the service it will be to the architect, that some horses have carried 650 or 700 lbs., and that for seven or eight miles, without resting, as their ordinary work; and, according to Desaguliers (*Experiment. Philos.* vol. i.), a horse at Stourbridge carried 11 cwt. of iron, or 1232 lbs., for eight miles.

Sect. IX.

AUTHORS ON EQUILIBRIUM OF ARCHES.

1351. The construction of arches may be considered in a threefold respect. I. As respects their form. II. As respects the mode in which their parts are constructed. III. As respects the thrust they exert.

1352. The first category involves rather the mode of tracing the right lines and curves whereof their surfaces are composed, and has been partially treated of in Section VI. on Descriptive Geometry, and will be further shortly discussed in future pages of this work. The other two points will form the subject of the present section.

1353. The investigation of the equilibrium of arches by the laws of statics does not appear to have at all entered into the thoughts of the ancient architects. Experience, imitation, and a sort of mechanical intuition seem to have been their guides. They appear to have preferred positive solidity to nice balance, and the examples they have left are rather the result of art than of science. Vitruvius, who speaks of all the ingredients necessary to form a perfect architect, does not allude to the assistance which may be afforded in the construction of edifices by a knowledge of the resolution of forces, nor of the aid that may be derived from the study of such a science as Descriptive Geometry, though of the latter it seems scarcely possible the ancients could have been ignorant, seeing how much it must have been (practically, at least) employed in the construction of such vast buildings as the Coliseum, and other similarly curved structures, as respects their plan.

1354. The Gothic architects seem, and indeed must have been, guided by some rules which enabled them to counterpoise the thrusts of the main arches of their cathedrals with such extraordinary dexterity as to excite our amazement at their boldness. But they have left us no precepts nor clue to ascertain by what means they reached such heights of skill as their works exhibit. We shall hereafter offer our conjectures on the leading principle which seems as well to have guided them in their works as the ancients in their earliest, and perhaps latest, specimens of columnar architecture.

1355. Parent and De la Hire seem to have been, at the latter end of the seventeenth century, the first mathematicians who considered an arch as an assemblage of wedge-formed stones, capable of sliding down each other's surfaces, which they considered in a state of the highest polish. In this hypothesis M. de la Hire has proved, in his *Treatise on Mechanics*, printed in 1695, that in order that a semicircular arch, whose joints tend to the centre, may be able to stand, the weights of the *voussoirs* or arch stones whereof it is composed must be to each other as the differences of the tangents of the angles which form each voussoir; but as these tangents increase in a very great ratio, it follows that those which form the springings must be infinitely heavy, in order to resist the effects of the superior voussoirs. Now, according to this hypothesis, not only would the construction of a semicircular arch be an impossibility, but also all those which are greater or less than a semicircle, whose centre is level with or in a line parallel with the tops of the piers; so that those only would be practicable whose centres were formed by curves forming angles with the piers, such as the parabola, the hyperbola, and the catenary. And we may here remark, that in parabolic and hyperbolic arches, the voussoir forming the keystones should be heavier or greater in height, and that from them the weight or size of the keystones should diminish from the keystone to the springing; the catenary being the only curve to which an horizontal *extrados*, or upper side, can be properly horizontal. In the *Memoirs of the Academy of Sciences*, 1729, M. Couplet published a memoir on the thrusts of arches, wherein he adopts the hypothesis of polished voussoirs; but, finding the theory would not be applicable to the materials whereof arches are usually composed, he printed a second memoir in 1730, wherein the materials are so grained that they cannot slide. But in this last he was as far from the truth as in his first.

1356. M. Danisy, a member of the Academy of Montpellier, liking neither of these hypotheses, endeavoured from experiments to deduce a theory. He made several models whose extradosses were equal in thickness, and divided into equal voussoirs, with piers sufficiently thick to resist the thrusts. To ascertain the places at which the failure would take place where the piers were too weak, he loaded them with different weights. From many experiments, in 1732, he found a practical rule for the walls or piers of a cylindrical arch so as to resist the thrust.

1357. Derand had thereupon found one which appears in his *Architecture of Arches*, but it seems to have been empirical. It was nevertheless adopted by Blondel and Deschalles, and afterwards by M. de la Rue.

Gautier, in his *Treatise on Bridges*, adopts one which seems to have had no better foundation in science than Derand's.

1358. At the end of a theoretical and practical treatise on stereotomy by M. Frezier, that author subjoined an appendix on the thrust of arches, which was an extract of what had theretofore been published by MM. de la Hire, Couplet, Bernouilli, and Danisy, with the applications of the rules to all sorts of arches. He seems to have been the first who considerably extended the view of the subject.

1359. Coulomb and Bossut occupied themselves on the subject. The first, in 1773, presented to the French Academy of Sciences a memoir on several architectural problems, amongst which is one on the equilibrium of arches. The last-mentioned author printed, in the *Memoirs* (1774 and 1776) of the same academy, two memoirs on the theory of cylindrical arches and of domed vaulting, wherein are some matters relating to the cupola of the Pantheon at Paris, whose stability was then a matter of doubt.

1360. In Italy, Lorgna of Verona considers the subject in his *Saggi di Statica Mecanica applicate alle Arti*; and in 1785, Mascheroni of Bergamo published, in relation to this branch of architecture, a work entitled *Nuove Ricerche delle Volte*, wherein he treats of cupolas on circular, polygonal, and elliptical bases.

1361. We ought, perhaps, not to omit a memoir by Bouguer in the Transactions of the French Academy of 1734, *Sur les Lignes Courbes propres a former les Voutes en Dome*, wherein he adduces an analogy between cylindrical and dome vaulting; the one being supposed to be formed by the movement of a catenarian curve parallel to itself, and the other by the revolution of the same curve about its axis.

1362. In this country, the equilibration of the arch, as given by Belidor and others on the Continent, seems to have prevailed, though little was done or known on the subject. Emerson seems to have been the earliest attracted to the subject, and in his *Treatise on Mechanics*, 1743, appears to have been the first who thought, after the Doctors Hooke and Gregory, of investigating the form of the extrados from the nature of the curve, in which he was followed by Hutton, who added nothing to the stock of knowledge; an accusation which the writer of this has no hesitation of laying at his own door, as having been the author of a *Treatise on the Equilibrium of Arches*, which has passed through two editions; but who, after much reflection, is now convinced, that, for the practical architect, no theory wherein the extrados is merely made to depend on the form of the intrados can ever be satisfactory or useful. It is on this account that in the following pages he has been induced to follow the doctrines of Rondelet, as much more satisfactory than any others with which he is acquainted.

1363. The formulæ of Rondelet were all verified by models, and the whole reasoning is conducted upon knowledge which is to be obtained by acquaintance with the mathematical and mechanical portions of the preceding pages. It moreover requires no deep acquaintance with the more abstruse learning requisite for following the subject as treated by later authors.

OBSERVATIONS ON FRICTION.

1364. I. In order that the stone parallelopiped ABCD (*fig.* 563.) may be made to slide upon the horizontal plane FG, the power which draws or pushes it parallel to this plane, must not be higher than the length of its base AB; for if it acts from a higher point, such as C, the parallelopiped will be overturned instead of sliding along it.

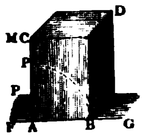


Fig. 563.

1365. As the effects of the powers P and M are in the inverse ratio of the heights at which they act, it follows that a parallelopiped will slide whenever the force which is necessary to overturn it is greater than that necessary to make it slide, and, reciprocally, it will be overturned when less force is necessary to produce that effect than to make it slide.

1366. II. When the parallelopiped is placed on an inclined plane, it will slide so long as the vertical QS drawn from its centre of gravity does not fall without the base AA. Hence, to ascertain whether a parallelopiped ABCD with a rectangular base (*fig.* 564.) will slide down or overturn; from the point B we must raise the perpendicular BE: if it pass out of the centre of gravity, it will slide; if, on the contrary, the line BE passes within, it will overturn.

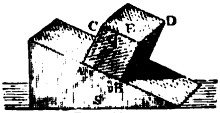


Fig. 564.

1367. If the surfaces of stones were infinitely smooth, as they are supposed to be in the application of the principles of mechanics, they would begin to slide the moment the plane upon which they are placed ceases to be perfectly horizontal; but as their surfaces are full of little inequalities which catch one another in their positions, Rondelet found, by repeated experiments, that even those whose surfaces are wrought in the best manner do not begin to slide upon the best worked planes of similar stone to the solids until such planes are inclined at angles varying from 28 to 36 degrees. This difficulty of moving one stone upon another increases as the roughness of their surfaces, and, till a certain point, as their weight: for it is manifest, 1st, That the rougher their surfaces, the greater are the inequalities which catch one another. 2d. That the greater their weight, the greater is the effort necessary to disengage them; but as these inequalities are susceptible of being broken up or bruised, the maximum of force wanting to overcome the friction must be equal to that which produces this effect, whatever the weight of the stone. 3d. That this proportion is rather as the hardness than the weight of the stone.

1368. In experiments on the sliding of hard stones of different sizes which weighed from 2 to 60 lbs., our author found that the friction which was more than half the weight for the smaller was reduced to a third for the larger. He remarked that after each experiment made with the larger stones a sort of dust was disengaged by the friction. In soft stones this dust facilitated the sliding.

1369. These circumstances, which would have considerable influence on stones of a great weight, were of little importance in the experiments which will be cited, the object being to verify upon hard stones, whose mass was small, the result of operations which the theory was expected to confirm. By many experiments very carefully made upon hard freestone well wrought and squared, it was found, 1st, That they did not begin to slide upon a plane of the same material equally well wrought until it was inclined a little more than 30 degrees. 2d. That to drag upon such stone a parallelopiped of the same material, a little more than half its weight was required. Thus, to drag upon a level plane a parallelopiped 6 in. long, 4 in. wide, and 2 in. thick, weighing 4 lbs. 11 oz., (the measures and weights are French, as throughout*), it was necessary to employ a weight equal to 2 lbs. 7 oz. and 4 drs. 3d. That the size of the rubbing surface is of no consequence, since exactly the same force is necessary to move this parallelopiped upon a face of two in. wide as upon one of 4.

1370. Taking then into consideration that by the principles of mechanics it is proved, that to raise a perfectly smooth body, or one which is round upon an homogeneous plane inclined at an angle of 30 degrees, a power must be employed parallel to the plane which acts with a force rather greater than half its weight, we may conclude that it requires as much force to drag a parallelopiped of freestone upon an horizontal plane of the same material as to cause the motion up an inclined plane of 30 degrees of a round or infinitely polished body.

1371. From these considerations in applying the principles of mechanics to arches composed of freestone well wrought, a plane inclined at 30 degrees might be considered as one upon which the voussoirs would be sustained, or, in other words, equivalent to an horizontal plane.

1372. We shall here submit another experiment, which tends to establish such an hypothesis. If a parallelopiped C (*fig.* 565.) of this stone be placed between two others, BD, RS, whose masses are each double, upon a plane of the same stone, the parallelopiped C is sustained by the friction alone of the vertical surfaces that touch it. This effect is a consequence of our hypothesis; for, the inequalities of the surfaces of bodies being stopped by one another, the parallelopiped C, before it can fall, must push aside the two others, BD, RS, by making them slide along the horizontal plane of the same material, and for that purpose a force must be employed equal to double the weight sustained.

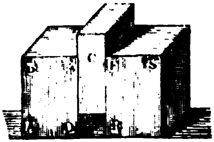


Fig. 565.

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* The Paris pound = 7561 Troy grains.
Ounce = 472·5625.
Dram or gros = 59·0703.
Grain = 0·8204.
And as the English avoirdupois pound = 7000 Troy grains, it contains 8538 Paris grains.
The Paris foot of 12 inches = 12·7977 English inches.

1373. If to this experiment the principles of mechanics be applied. considering the plane of 30 degrees inclination as a horizontal plane, the vertical faces ED FR may be considered as inclined planes of 60 degrees. On this hypothesis it may be demonstrated by mechanics, that to sustain a body between two planes forming an angle of 60 degrees (*fig. 566.*), the resistance of each of these planes must be to half the weight sustained as HD is to DG, as the radius is to the sine of 30 degrees, or as 1 is to 2.

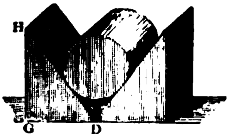


Fig. 566.

EQUILIBRIUM OF ARCHES.

1374. The resistance of each parallelopiped represented by the prism ABDE (*fig. 565.*) being equal to half their weight, it follows that the weight to be sustained by the two prisms should equal one quarter of the two parallelopipeds taken together, or the half of one, which is confirmed by the experiment. This agreement between theory and practice determined Rondelet to apply the hypothesis to models of vaults composed of voussoirs and wedges disunited, made of freestone, with the utmost exactness, the joints and surfaces nicely wrought, as the parallelopipeds in the preceding example.

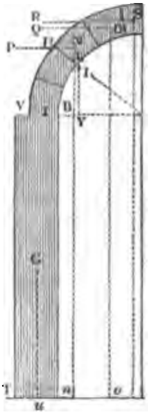


Fig. 567.

1375. The first model was of a semicircular arch 9 inches diameter, comprised between two concentric semi-circumferences of circles 21 lines apart. It was divided into 9 equal voussoirs. This arch was 17 lines deep, and was carried on piers 2 inches and 7 lines thick. It was found, by gradually diminishing the piers, which were at first 2 inches and 10 lines thick, that the thickness first named was the least which could be assigned to resist the thrust of the voussoirs.

1376. The model in question is represented in *fig. 567.*, whereon we have to observe, — 1st. That the first voussoir, I, being placed on a level joint, not only sustains itself, but is able to resist by friction an effort equal to one half of its weight. 2d. That the second voussoir, M, being upon a joint inclined 20 degrees, will also, through friction, sustain itself; and that, moreover, these two voussoirs would resist, previous to giving way on the joint AB, an horizontal effort equal to one half of their weight. 3d. That the third voussoir, N, standing on a joint inclined at 40 degrees, would slide if it were not retained by a power PN acting in an opposite direction. 4th. That taking, according to our hypothesis, an inclined plane of 30 degrees, whereon the stones would remain in equilibrium as an horizontal one, the inclined point of 40 degrees may be considered as an inclined plane of 10 degrees, supposing the surfaces infinitely smooth. 5th. That the effort of the horizontal power which holds this voussoir in equilibrium upon its joints will be to its weight as the sine of 10 degrees is to its cosine, as we have, in the section on Mechanics, previously shown. (1255 et seq.)

1377. The model of the vault whereon we are speaking being but 9 inches, or 108 lines in diameter, by 21 lines for the depth of the voussoirs, that is, the width between the two concentric circumferences, its entire superficies will be 4257 square lines, which, divided by 9, gives for each voussoir 473 square lines. Then, letting the weight of each voussoir be expressed by its superficies, and calling P the horizontal power, we have

$$P : 473 :: \text{sin. } 10^\circ : \text{cosin. } 10^\circ;$$
$$\text{Or, } P : 473 :: 17365 : 98481 \text{; which gives } P = 83\tfrac{4}{10}.$$

The fourth voussoir, being placed upon a bed inclined at 60 degrees, will be considered as standing on a plane inclined only at 30 degrees, which gives, calling Q the horizontal power which keeps it on its joint, —

$$Q : 473 :: \text{sin. } 30^\circ : \text{cosin. } 30^\circ.$$
$$\text{Or, } Q : 473 :: 50000 : 86603 = 273\tfrac{3}{10}.$$

1378. The half-keystones, being placed on a joint inclined 80 degrees, are to be considered as standing on an inclined plane of 50, the area of the half key which represents its weight being $236\tfrac{1}{2}$. If we call R the horizontal power which sustains it on its joint, we shall have the proportion

$$R : 236\tfrac{1}{2} :: \text{sin. } 50 : \text{cosin. } 50;$$
$$\text{or, } R : 236\tfrac{1}{2} :: 76604 : 64279 \text{; which gives } R = 281\tfrac{9}{10}.$$

1379. Wishing to ascertain if the sum of these horizontal efforts, which were necessary to keep on their joints the two voussoirs N, O, and the half-keystone, was capable of thrusting away the first voussoir upon its horizontal joint AB, the half arch was laid down upon a level plane of the same stone without piers, and it was proved that to make it give way an horizontal effort of more than 16 ounces was required, whilst only 10 were necessary to sustain the half-keystone and the two voussoirs N, O. The two halves of the arches united bore a weight of 5 lbs. 2 oz. before the first voussoirs gave way.

1380. To find the effect of each of these voussoirs when the arch is raised upon its piers, let fall from the centres of gravity N, O, S of these voussoirs the perpendiculars N*n*, O*o*, S*s*, in order to obtain the arms of the levers of the powers P, Q, R, which keep them in their places, tending at the same time to overturn upon the fulcrum T the pier which carries the half arch, and we have their effort —

$$\mathrm{P} \times \mathrm{N}n + \mathrm{Q} \times \mathrm{O}o + \mathrm{R} \times \mathrm{S}s.$$

The height of the pier being 195 lines, we have

$$\mathrm{N}n = 244{\cdot}94$$
$$\mathrm{O}o = 256{\cdot}26$$

and $\mathrm{S}s = 260{\cdot}50$, whence we have

The effort $\mathrm{P} \times \mathrm{N}n = 83{\cdot}4 \times 244{\cdot}94$, which gives 20427·996
$\mathrm{Q} \times \mathrm{O}o = 273{\cdot}3 \times 256{\cdot}26$ . . . . 70035·858
$\mathrm{R} \times \mathrm{S}s = 281{\cdot}9 \times 260{\cdot}50$ . . . . 73434·950

Total effort in respect of the fulcrum, 163898·804

1381. The pier resists this effort, 1st, by its weight or area multiplied by the arm of the lever determined by the distance T*u* from the fulcrum T to the perpendicular let fall from the centre of gravity G upon the base of the pier. 2d. By the weight of the half arch multiplied by the arm of its lever VY determined by the vertical LY let fall from the centre of gravity L, and which becomes in respect of the common fulcrum T = T*t* or VB − BY, in order to distinguish BY, which indicates the distance of the centre of gravity of the half arch (and which is supposed known because it may be found by the rules given in 1275. et seq.) from the width VB that the pier ought to have to resist the effort of the half arch sought. In order to find it, let P, the effort of the arch above found, be 163898·804.

Let the height of the pier $= a$
The width sought $= x$
The weight of the half arch $= b$
The part BY of its arm of lever $= c$

1382. The area of the pier which represents its weight multiplied by the arm of the lever will be $ax \times \frac{x}{2} = \frac{axx}{2}$. That of the half arch multipied by its arm of lever will be shown by VB + BY, where $x + c$ will be $bx + bc$, whence the equation $\mathrm{P} = \frac{axx}{2} + bx + bc$, which we have to solve.

Now first we have $\frac{axx}{2} + bx = \mathrm{P} - bc.$

Multiplying all the terms by $\frac{2}{a}$ to eliminate xx, we have $xx + \frac{2bx}{a} = \frac{2p - 2bc}{a}$, an expression in which x is raised to the second power; but as $xx + \frac{2bx}{a}$ is not a perfect square, that is to say, it wants the square of half the known quantity $\frac{2b}{a}$ which multiplies the second term; by adding this square, which is $\frac{bb}{aa}$, to each side of the equation, we have $xx + \frac{2bx}{a} + \frac{bb}{aa} = \frac{2p - 2bc}{a} + \frac{bb}{aa}$. The first member by this means having become a perfect square whose root is $a + \frac{b}{a}$, we shall have $x + \frac{b}{a} + \sqrt{\frac{2p - 2bc}{a} + \frac{bb}{aa}}$, which becomes, by transferring $\frac{b}{a}$ to the other side of the equation, $x = \sqrt{\frac{2p - 2bc}{a} + \frac{bb}{aa}} - \frac{b}{a}$, in which x being only in the first member of the equation, its value is determined from the known quantities on the other side. Substituting, then, the values of the known quantities, we have

$$x = \sqrt{\frac{163898{\cdot}804 \times 2 - 2128 \times 2 \times 12\tfrac{1}{4}}{195} + \frac{2128}{195} \times \frac{2128}{195}} - \frac{2128}{195},$$

which gives $x = 28\frac{1}{4}$ lines instead of 2 inches and 5 lines, which was assigned to the piers that they might a little exceed equilibrium in their stability.

Proof of the above Method by another Method of estimating Friction.

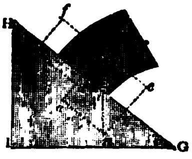


Fig. 568.

1383. A proof of the truth of the hypothesis in the preceding section is to be found in the method proposed by Bossut in his *Treatise on Mechanics*.

Let the voussoir N (*fig.* 568.) standing on an inclined plane be sustained by a power Q acting horizontally. From the centre of gravity let fall the vertical Nn, which may be taken to express the weight of the voussoir. This weight may be resolved into two forces, whereof one, Nc, is parallel to the joint, and the other Na is perpendicular to it. In the same manner the power Q expressed by QN in its direction may be resolved into two forces, whereof Nf will be parallel to the joint and the other Nd perpendicular to it. Producing the line from the joint HG, drawing the horizontal line GI and letting fall the vertical HI, consider the line HG as an inclined plane whose height is HI and base IG. Then the force Nc with which the voussoir will descend will be to the weight as the height HI of the inclined plane is to its length HG. Calling p the weight of the voussoir, we then have $Nc = p \times \frac{HG}{HI}$, and the force N$a$ which presses against the plane as the base of the plane IG is to its length, which gives the force $Na = p \times \frac{IG}{HG}$.

1384. Considering, in the same way, the two forces of the power Q which retain the voussoir on the inclined plane, we shall find the parallel force $Nf = Q \times \frac{IG}{GH}$, and the perpendicular force $Nd = Q \times \frac{IH}{HG}$. The force resulting from the two forces Na, Nd, which press against the joint, will be expressed by $p \times \frac{IG}{HG} + Q \times \frac{H}{GH}$; and as the voussoir only begins to slide upon a plane whose inclination is greater than 30 degrees, the friction will be to the pressure as the sine of 30 degrees is to its cosine, or nearly as 500 is to 866, or $\frac{500}{866}$ of its expression. Calling this ratio n, we shall, to express the friction, have

$$\left(p \times \frac{IG}{GH} + Q \times \frac{IG}{GH}\right) \times n.$$

As the friction prevents the voussoir sliding on its joint, in a state of equilibrium, we shall have the force Nf equal to the force Nc, less the friction; from which results the equation—

$$Q \times \frac{IG}{HG} = p \times \frac{HI}{HG} - \left(p \times \frac{IG}{GH} - Q \times \frac{IH}{HG}\right) \times n.$$

All the terms of which equation having the common divisor HG, it becomes —

$$Q \times IG = p \times HI - (p \times IG - Q \times IH) \times n;$$

and, bringing the quantities multiplied by Q to the same side of the equation, we have

$Q \times IG + (Q \times IH) \times n = p \times HI - (p \times IG) \times n$; which becomes
$Q \times (IG + n \times IH = p \times (HI - n \times IG)$; whence results
$Q = p \times \frac{HI - n \times IG}{IG + n \times IH}$, which is the formula for each voussoir, substituting the values for the expression.

1385. Thus for the third voussoir N (*fig.* 567.) placed on an inclined plane of 40 degrees, HI which represents the sine of the inclination will be 643, and its cosine represented by IG, 766, the expression of the friction n will be $\frac{500}{866}$, or $\frac{15}{26}$ nearly. The weight of the voussoir expressed by its area will be 473, which several values being substituted in the formula, we have

$$Q = 473 \times \frac{643 - \frac{15}{26} \times 766}{766 + \frac{15}{26} \times 643};$$

which gives $Q = 83{\cdot}6$, the expression of the horizontal force P, which will keep the voussoir N in equilibrium on its joint instead of 83·4, which was the result of the operation in the preceding subsection.

1386. The same formula $Q = p \times \frac{HI - n \times IG}{IG + n \times IH}$ gives for the voussoir M on an inclined joint of 60 degrees, whose sine HI is 866 and cosine IG 500, $Q = 473 \times \frac{886 - \frac{15}{26} \times 500}{500 + \frac{15}{26} \times 866} = 273{\cdot}4$; instead of 273·3, which was the result of the operation in the preceding section.

1387. For the half-keystone, the sine HI, being of 80 degrees, will be expressed by 985, and its cosine IG by 174; the half-keystone by 236½, and the friction by $\frac{15}{26}$.

The formula now will be $Q = 236\frac{1}{2} \times \frac{985 - \frac{15}{16} \times 174}{174 + \frac{15}{16} \times 985}$, which gives $Q = 282{\cdot}2$, instead of $281\frac{2}{10}$ found by the other method. These slight differences may arise from suppressing the two last figures of the sines, and some remainders of fractions which have been neglected. Multiplying these values of the powers which keep the voussoirs in equilibrium upon their beds by the several arms of the levers, as in the preceding calculations, their energy will be as follows: —

For the voussoir N, 83·6 × 244·94 = 20476·98
— O, 273·4 × 256·26 = 70061·48
— S, 282·2 × 260·50 = 73313·10

For the total force in respect of the fulcrum T = 163851·56.

Which is the value of p, and being substituted for it in the formula $x = \sqrt{\frac{2p - 2bc}{a} + \frac{bb}{aa}} - \frac{b}{a}$, as well as the values of the other letters, which are the same as in the preceding example, we have

$$x=\sqrt{\frac{163851\cdot56\times2-2128\times2\times12\tfrac{1}{2}}{195}+\frac{2128}{195}\times\frac{2128}{195}}-\frac{2128}{195}=28\cdot16 \text{ lines}$$

for the thickness of the piers, instead of 28¼ lines found by the preceding operation.

Application of the Principles in the Model of a straight Arch.

1388. The second model to which the application of the preceding methods was made was a straight arch of the same sort (*fig.* 569.), whose opening between the piers was 9 inches. The arch was 21 lines high and 18 lines thick. It was divided into 9 wedges, whose joints were concentric. To determine the section of the joints, the diagonal FG was drawn on the face of the half arch, and from its extremity F touching the pier, the perpendicular FO meeting O in the vertical, passing through the middle of the opening of the piers, all the sections meeting in this point O. Each of the sections of the piers which support the arch forms an angle of 21° 15′ with the vertical, and of 68° 45′ with the horizon.

1389. In considering each of the wedges of the half arch as in the preceding method, it will be found that in order to retain the voussoir A on the joint IF (of the pier) which forms with the horizontal line NF an angle of 68° 45′, we have

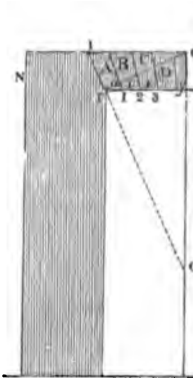


Fig. 569.

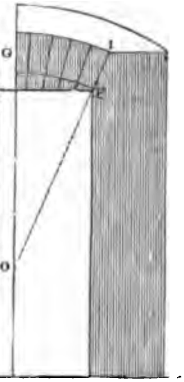


Fig. 570.

For the horizontal force	- - -	217·50
second B	- - -	254·33
third C	- - - -	298·75
fourth D	- - - -	354·66
half-keystone	- - -	212·83
	Total -	1338·07

The height of the piers being 195 lines to the underside of the arch, and 216 to the top of the extrados, it follows that the arm of the lever, which is the same for all the wedges, is 206⅓, from which we derive for the thrust p of the formula,

$$x=\sqrt{\frac{2p-2bc}{a}+\frac{bb}{aa}}-\frac{a}{b}$$

$$=1338\cdot07\times206\cdot33=276084;$$

b which expresses the area of the half arch $=1219\tfrac{1}{2}$; c which expresses the distance of its centre of gravity from the vertical $Fn=24$, and the height of the pier $a=216$. Now, substituting these values in the formula, we shall have

$$a=\sqrt{\frac{276084\times2-2439\times24}{216}+\frac{1219\tfrac{1}{2}\times1219\tfrac{1}{2}}{216\times216}}-\frac{1219\tfrac{1}{2}}{216}=42\tfrac{1}{2} \text{ lines.}$$

Experiment gives 44 lines for the least width of the piers upon which the model will stand. But it is right to observe that from the impossibility of the joints being perpendicular to the intrados, the forces of the wedges press in a false direction on each other, as will be seen by the lines Fa, 1c, 2e, 3g, perpendicular to the joints against which the forces are directed, so that such an arch will only stand when the perpendicular FG does not fall within the thickness of the arch; and, indeed, this sort of arch is only secure when it comprises an arc whose width is equal to the section upon the piers IF, as shown in *fig.* 570.

Observations on the Way in which Stones forming an Arch act to support one another.

1390. Let the semicircular arch AHCDNB (*fig.* 571.) consist of an infinite number of voussoirs acting without friction, and only kept in their places by their mutual forces acting on each other. It will follow —

1. That the first voussoir, represented by the line AB, having its joints sensibly parallel and horizontal, will act with its whole weight in the vertical direction IE to strengthen the pier.

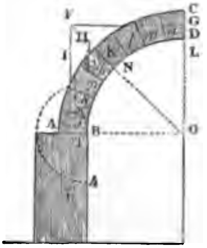


Fig. 571.

2. That the vertical voussoir CD, which represents the keystone, having also its joints sensibly parallel, will act with its whole weight horizontally to overturn the semi-arches and piers which carry them.

3. That all the other voussoirs between these two extremes will act with the compound forces G*n*, *nm*, *ml*, K*l*, K*h*, *hg*, *gf*, *f*T, which may each be resolved into two others, whereof one is vertical and the other horizontal: thus the compound force K*h* is but the result of the vertical force 4*h*, and the horizontal force 4K.

4. That the vertical force of each voussoir diminishes from T to G, where, for the keystone CD, it becomes nothing, whilst the horizontal forces continually increase in an inverse ratio; so that the voussoir HN, which is in the middle, has its vertical and horizontal forces equal.

5. That in semi-circular arches whose extradosses are of equal height from their intradosses, the circumference passing through the centre of gravity of the voussoirs may represent the sum of all the compound forces with which the voussoirs act upon one another in sustaining themselves, acting only by their gravity.

6. That if from the points T and G the vertical TF and horizontal GF be drawn meeting in the point F, the line TF will represent the sum of the vertical forces which assist the stability of the pier, and FG the sum of the horizontal forces which tend to overthrow it.

7. That if through the point K the horizontal line IKL be drawn between the parallels FT and CO, the part IK will represent the sum of the horizontal forces of the lower part AHNB of the vault, and KL those of the upper part HCDN.

8. The lower voussoirs between T and K being counterpoised by their vertical forces, the part of the arch AHNB will have a tendency to fall inwards, turning on the point B, whilst the voussoirs between K and G being counterpoised by their horizontal forces, the part HCDN of the arch will re-act upon the lower part by its tendency to turn upon the point A.

9. The horizontal forces of the upper part of the arch shown by KL acting from L towards K, and those of the lower part shown by IK opposite in direction to the former, that is, from I to K, being directly opposed, would counterpoise each other if they were equal, and the arch would have no thrust; but as they are always unequal, it is the difference of the forces which occasions the thrust, and which acts in the direction of the strongest power.

10. If we imagine the width BO of a semi-arch constantly to diminish, its height remaining the same, the sum of the horizontal forces will diminish in the same ratio, so that when the points B and O are common, the horizontal force being annihilated, nothing remains but the vertical force, which would act only on the pier, and tend to its stability, thrust vanishing, because, instead of an arch, it would, in fact, be nothing more than a continued pier.

11. If, on the contrary, the height OD diminishes, the width BO remaining the same, the curve B and D would, at last, vanish into the right line BO, and the arch would become a straight one. In this case, the vertical forces which give stability to the pier being destroyed, all that remains for sustaining the arch are the horizontal forces which will act with the whole weight of the arch; whence this species of arches must be such as exert most thrust, and circular arches hold a middle place between those which have no thrust, and flat arches, whose thrust is infinite, if the stones whereof they are formed could slide freely on one another, and their joints were perpendicular to their lower surfaces, as in other arches.

12. The inconveniences which result from making the joints of flat arches concentric have been before noticed. If the stones could slide freely on one another, as they only act in a false direction, their forces could never either balance or destroy one another.

13. A vast number of experiments made by Rondelet, upon fifty-four models of arches of different forms and extradosses, divided into an equal and unequal number of voussoirs, showed that the voussoirs acted rather as levers than as wedges, or as bodies tending to slide upon one another.

14. As long as the piers are too weak to resist the thrust of the voussoirs, many of them unite as one mass, tending to overturn them on a point opposite to the parts where the joints open.

15. Arches whose voussoirs are of even number exert more thrust than those which are of unequal number, that is, which have a keystone.

16. In those divided into uneven numbers and of unequal size, the larger the keystone the less is their thrust, so that the case of the greatest thrust is when a joint is made at the vertex, as in the case of arches whose voussoirs are divided into equal numbers.

17. A semicircular arch divided into four equal parts has more thrust than one divided into nine equal voussoirs.

18. Arches including more than a semicircle have less thrust than those of a similar span, the intradosses and extradosses being of similar forms.

19. Thrust does not increase as the thickness of an arch increases; so that, *cæteris paribus*, an arch of double the thickness has not double the thrust.

20. A semicircular arch whose extrados is equally distant throughout from, or, in other words, concentric with, the intrados, when divided into four equal parts, will only stand when its depth is less than the eighteenth part of its diameter, even supposing the abutments immoveable.

21. Whenever, in an arch of voussoirs of equal depth, a right line can be drawn from its outer fulcrum to the centre of the extrados of the keystone (*fig.* 572.), fracture does not occur in the middle of the haunches if the piers are of the same thickness as the lower part of the arch.

22. Arches whose thickness or depth diminishes as they rise to the vertex have less thrust than those whose thickness is equal throughout.

23. Semicircular and segmental arches whose extrados is an horizontal line have less thrust than others.

24. As long as the piers in the models were too weak to resist the thrust, it was possible to keep them in their places by a weight equal to double the difference between the thrust and resistance of one pier, acting by a string suspended passing through the joints in the middle of the haunches, or by a weight equal to that difference placed above each middle joint of the arches, as in *fig.* 572.

From these experiments and many others, a formula has been deduced to determine the thickness of piers of cylindrical arches of all species whose voussoirs are of equal depth, whatever their forms; and to this we shall now introduce the reader.

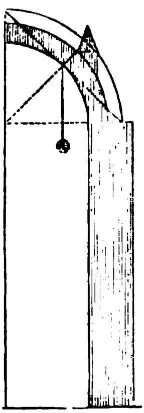


Fig. 572.

Method.

1391. Having described the mean circumference GKT (*figs.* 573, 574.), from the points G and T draw the tangents to the curve meeting in the point F. From this point draw the perpendicular FO cutting it in the point K. This point is the place of the greatest effort, and of the consequent failure, if the thickness of the piers is too weak to resist the thrust.

1392. Through the point K, between the parallels TF and GO, draw the horizontal line IKL, which will represent the sum of the horizontal forces as will the vertical TF express the vertical forces; the mean circumference GKT will express the compound forces.

1393. The arches having an equal thickness throughout, the part IK of the horizontal line multiplied by the thickness of the arch will express the horizontal effect of the lower part of either arch, and KL multiplied by the same thickness will express that of the upper part. These two forces acting in opposite directions will partly destroy each other; thus transferring IK from K to *m*, the difference *m*L multiplied by the thickness of the vault will be the expression of the thrust. This force acting at the point K in the horizontal direction KH, the arm of the lever is determined by the perpendicular PH raised from the fulcrum P of the lever to the direction of the thrust, so that its effort will be expressed by *m*L × AB × PH.

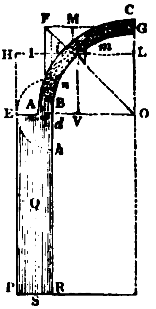


Fig. 573.

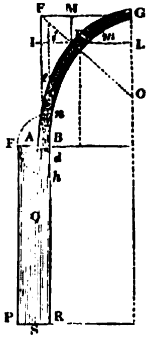


Fig. 574.

This will be resisted —

1. By its weight represented by the surface EP × PR multiplied by the arm of the lever PS, determined by a vertical let fall from the centre of gravity Q, which gives for the resistance of the pier the expression EP × PR × PS.

2. By the sum of the vertical efforts of the upper part of each arch, represented by MK × AB acting at the point K, the arm of their lever in respect of the fulcrum P of the pier being KH.

3. By the sum of the vertical efforts of the lower part represented by IT multiplied by AB acting on the point T has for the arm of its lever TE. Hence, if equilibrium exist,

$$\overline{mL} \times \overline{AB} \times PH = \overline{PE} \times \overline{PR} \times PS + \overline{MK} \times \overline{AB} \times KH + \overline{IT} \times \overline{AB} \times TE.$$

But as in this equation neither PR (= BE) nor PS nor KH nor TE is known, we must resort to an algebraic equation for greater convenience, in which

The effect of the thrust in the expression *m*L × AB $= p$
The height of the pier PE - - - - $= a$
EH = TI = KL = KV - - - - - $= d$
PH - - - - - - - $= a + d$
EB = PR - - - - - - $= x$

PS - - - - - - - $=\frac{x}{2}$

The sum of the vertical forces of the upper part or MK × AB - - - - - $=m$

The sum of the forces of the lower part IT × AB $=n$

The part *i*K of the horizontal IKL - - $=c$

TB equal to half the thickness of the arch - $=e$

The arm of the lever KH - - - $=c\times x$

That of TE - - - - - $=x-e$

Thus the first equation becomes $pa+pd=\frac{axx}{2}+m\ (c\times x)+n\ (x-e)$,

Or $pa\times pd=\frac{axx}{2}+mx+mc+nx-ne.$

Transferring the unknown quantities to the second side of the equation, we shall have $\frac{axx}{2}+mx+nx=pa+pd+ne-mc.$

Multiply all the terms by 2, and divide by a, in order to get rid of xx, and we have $xx+\frac{2(m+n)x}{a}=2p+\frac{2pd+2nc-2mc}{a}$;

Making $m+n=b$, and adding to each member $\frac{bb}{aa}$ for the purpose of extracting the root of the first member,

We have $xx+\frac{2bx}{a}+\frac{bb}{aa}=2p+\frac{2pd+2ne-2mc}{a}+\frac{bb}{aa}$.

Extracting the root, $x+\frac{b}{a}=\sqrt{2p+\frac{2pd+2ne-2mc}{a}+\frac{b}{aa}}$;

And lastly, $x=\sqrt{2p+\frac{2pd+2ne-2mc}{a}+\frac{bb}{aa}}-\frac{b}{a}$.

1394. This last equation is a formula for finding the thickness of all sorts of arches whose voussoirs are of equal depth, which we will now apply to *fig.* 573. The model was 36 inches and 3 lines in span. The arch consisted of two concentric circles, and it was divided into four equal parts, a vertical joint being in the middle, the two others being inclined at angles of 45 degrees. The piers whereon it was placed were 40 inches and 4 lines high, and on a very exact measurement the values were as follow: —

PE (a in the formula) was - - - - -	40·333
EH = TI = KL = KV (d in the formula) - - -	13·876
ML × AB (p in the formula) representing the thrust or 8·127 × 3	24·381
$2p$ - - - - - - - -	48·762
$2pd=48{\cdot}762\times 13{\cdot}876$ - - - - -	676·621
2MK × AB × KH represented by $2mc$ ($=5{\cdot}749\times 3\times 4{\cdot}249$) -	73·282
$2ne$, which is IT × AB × AB ($=13{\cdot}876\times 3\times 3$) - -	124·824
$b=m+n=$(MK + IT) × AB ($=19{\cdot}625\times 3$) - - -	58·875
$a=$ EP, the height of the pier being 40·333, $\frac{b}{a}$ will be $\frac{58{\cdot}875}{40{\cdot}333}$ or	1·459
$\frac{bb}{aa}$ - - - - - - - -	2·128

Substituting these values in the formula $x=\sqrt{2p+\frac{2pd+2ne-2mc}{a}+\frac{bb}{aa}}-\frac{b}{a}$,

we have $x=\sqrt{48{\cdot}762+\frac{676{\cdot}621+124{\cdot}824-73{\cdot}282}{40{\cdot}333}+2{\cdot}128}-1{\cdot}459$;

which gives $x=5{\cdot}8$, or 5 inches 9½ lines for the thickness of the piers to resist the thrust of the arch, supposing it to be perfectly executed. But, from the imperfection of the execution of the model, it was found that the piers required for resisting the thrust a thickness of 6 inches and 3 lines.

1395. When the piers of the model were made 7⅓ inches thick the arch on its central joint was found capable of supporting a weight of three pounds, being equal to an addition of 8 superficial inches beyond that of the upper parts of the arch which are the cause of the thrust, and this makes the value of $2p$ in the formula 56·762 instead of 48·762, and changes the equation to $x=\sqrt{56{\cdot}762+\frac{787{\cdot}629+124{\cdot}828-86{\cdot}458}{40{\cdot}333}+2{\cdot}430}-1{\cdot}55$; from which we should obtain $x=7{\cdot}366$ inches, or 7 inches 3⅓ lines, exhibiting a singular agreement between theory and practice. Rondelet gives another method of investigating the preceding problem, of which we do not think it necessary to say more than that it agrees with that just exhibited so singularly that the result is the same. It is dependent on the places of the centres of gravity, and therefore not so readily applicable in practice as that which has been just given.

Second Experiment.

1396. *Fig.* 567., in a preceding page, is the model of an arch in freestone, which has been before considered. It is divided into nine equal voussoirs, whose depth to the extrados is 21 lines, and whose interior diameter is 9 inches.

1397. Having drawn the lines heretofore described, we shall find $mL \times AB$ expressed in the formula by

$p = 26{\cdot}7 \times 21$, which gives	560·70
And for $2p$	1121·40
$EH = TI = KL = KV$, expressed by d, will be	45·60
Hence $2pd$	5113·584
$2ne$, which is twice the vertical effort of the lower part of the arch, multiplied by ½ AB, will be $45{\cdot}6 \times 21 \times 21$, which gives	20109·60
$2me$, which indicated twice the vertical effort of the upper part, multiplied by iK, will be $18{\cdot}9 \times 21 \times 2 \times 8{\cdot}4$, which gives	6667·92
a, which represents the height of the piers, being 195, and $b = m + n = 64{\cdot}5 \times 21 = 1354{\cdot}5$, $\frac{b}{a}$ will become $\frac{1354{\cdot}5}{195}$	6·94

And all these values being substituted in the formula, will give

$$x = \sqrt{1121{\cdot}40 + \frac{5113{\cdot}584 + 20109{\cdot}6 - 6667{\cdot}92.}{195} + 48{\cdot}163 - 694} = 28{\cdot}62 \text{ lines},$$

instead of 28½, before found.

Geometrical Application of the foregoing.

1398. Let the mean curve TKG of the arch (whatever its form) be traced as in *figs.* 573, 574., the secant FO perpendicularly to the curve of the arch, and through the point K, where the secant cuts the mean curve, having drawn the horizontal line IKL, and raised from the point B a vertical line meeting the horizontal IKL in the point i, draw iK from K to m, and the part mL from B to h, and the double thickness of the arch from B to n. Let hn be divided into two equal parts at the point d, from which as a centre with a radius equal to half hn, describe the semi-circumference of a circle which will cut in E the horizontal line BA prolonged. The part BE will indicate the thickness to be given to the piers of the arches to enable them to resist the thrust.

1399. The truth of the method above given depends upon the graphic solution of the following problem: To find the side BE of a square which shall be equal to a given surface $mL \times 2e$; an expression which is equivalent to $2p$, and we have already seen that $x = \sqrt{2p}$ was a limit near enough; hence we may conclude that the thickness BE obtained by the geometrical method will be sufficiently near in all cases.

Experiments on surmounted Arches.

1400. The interior curve of *fig.* 574. is that of a semi-ellipsis 81 lines high; it is divided into four parts by an upright joint in the crown and two others towards the middle of the haunches determined by the secant FO, perpendicular to the interior part of the curve. Having traced the mean circumference GKT, the horizontal IKL, and the vertical Bi, we shall find

KL	36¾
IK	21¾
iK	17¼
IT	66½
$MK = d$	19
The effect of the thrust indicated by $KL - iK = mL$ will be $19\frac{1}{2} \times 9$, which gives for the expression p of the formula	175·5
$2p$ therefore	351·0
d being 66·5, $2pd$ will be $351 \times 66{\cdot}5$, which gives	23341·5
m, which is $KM \times AB$, will be 19×9, which gives	171·0
c, that is, iK, being 17¼ lines, we have $2me = 171 \times 17\frac{1}{4} \times 2$, which gives	5899·50
The height of the piers a	120·00
b, which expresses the sum of the vertical efforts $m + n$, will be equal to $MK + IT \times AB$ or $19 + 66\frac{1}{2} \times 9$, which gives	769·50
Hence $\frac{b}{a} = \frac{769{\cdot}5}{120}$, which gives	6·41
And $\frac{bb}{aa}$ gives	41·11

Substituting these values in the formula, $x = \sqrt{2p + \frac{2pd - 2mc}{a} + \frac{bb}{aa}} - \frac{b}{a}$,

We have the equation $x = \sqrt{351 + \frac{23341{\cdot}5 - 5899{\cdot}5}{120} + 41{\cdot}11} - 6{\cdot}41 = 16{\cdot}77$

lines, or a little more than 16¾ lines. The model of this arch would not however stand on piers less than 17 lines thick.

In taking the root of double the thrust the result is 18¾ lines, as it is also by the geometrical method.

Application to the Pointed Arch.

1401. The model which *fig.* 575. represents was of the same height and width as the last, and the voussoirs were all of equal thickness. Having laid down all the lines on the figure as before, we shall find *i*K of the formula to be

$$x = \sqrt{2p + \frac{2pd - 2mc}{a} + \frac{bb}{aa}} - \frac{b}{a} \text{ wherein}$$

c = 20
KL = 34
*m*L = 14
IT, represented by *d*, = 63
MK = 23
AB = 9
*m*L × AB, represented by *p* in the formula, will be 14 × 9 = 126
and 2*p* = 252
2*pd* will be 252 × 63, which gives = 15876
m, which is KM × AB or 23 × 9, = 207
2*m* = 414, 2*mc* = 414 × 20 = 8280

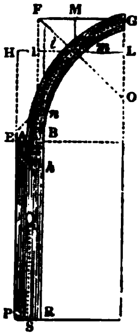


Fig. 575.

The height of the pier, represented by *a*, being 120, we have $\frac{2pd-2mc}{a} = \frac{15876-8220}{120} = 63{\cdot}8$; *b*, or FT × AB, will be 86 × 9 = 774; whence $\frac{b}{a} = \frac{774}{120} = 6{\cdot}45$, and $\frac{bb}{aa} = 41{\cdot}60$. Substituting these values in the formula

$$x = \sqrt{252 + 63{\cdot}8 + 41{\cdot}6} - 6.45 = 12{\cdot}46 \text{ lines for the thickness of the pier.}$$

In taking the square root of double the thrust the thickness comes out 15·88 lines, as it does by the geometrical method. Experiments showed that the least thickness of piers upon which the model would stand was 14 lines.

Application to a surmounted Catenarean Arch.

1402. The lines are all as in the preceding examples (*fig.* 576.). The whole arch acts on the pier in the direction FT, which is resolved into the two forces T*f* and T*m*, and the formula, as before, is

$$x = \sqrt{2p + \frac{bb}{aa}} - \frac{b}{a};$$

thus having found B*m* = 22⅓, we have the value of $p = 22\frac{1}{3} \times 9 = 201$; and $2p = 402$.

1403. This model was of the same dimensions as the preceding: *b*, which represents T*f* × AB, will be 769·5; $\frac{bb}{aa}$ will be 6·41, and $\frac{b}{a} = \frac{769{\cdot}5}{120} = 41{\cdot}11$. These values substituted in the formula give

$$x = \sqrt{402 + 41{\cdot}11} - 6{\cdot}41 = 14{\cdot}64 \text{ lines.}$$

1404. Experiment determined that the pier ought not to be less than 16 lines, and the geometrical method made it 28.

The following table shows the experiments on six different models.

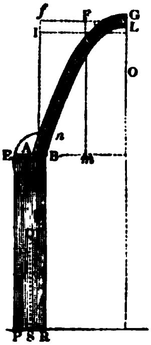


Fig. 576.

Form of Arch.	Thickness of the Piers.		
	By the formula.	By experiment.	Geometrically.
	Lines.	Lines.	Lines.
The pointed	12·46	14·00	15·88
The catenary	14·64	15·00	20·05
The cycloid	14·66	15·00	17·24
The parabolic	15·85	16·50	21·30
The elliptic	16·77	17·00	18·75
The cassinoid	19·62	21·00	20·79

This table shows that, in practice, for surmounted arches, the limit $x = \sqrt{2p}$, or the thickness obtained for the construction by graphical means is more than sufficient, since it gives results greater than those that the experiments require, excepting only in the cassinoid; but even in the case of that curve the graphical construction comes nearer to experiment than the result of the first formula.

1405. It is moreover to be observed, that the pointed is the most advantageous form for surmounted arches composed of arcs of circles. We have had occasion to speak, in our First Book, of the boldness and elegance exhibited in this species of arches by the architects of the twelfth and thirteenth centuries; we shall merely add in this place that where roofs are required to be fire-proof, there is no form so advantageously capable of adoption as the pointed arch, nor one in which solidity and economy are so much united.

1406. Next to the pointed arch for such purpose comes the catenary (the graphical method of describing which will be found under its head, in the Glossary at the end of the work), and this is more especially useful when we consider that the voussoirs may all be of equal thickness.

Application of the Method to surbased Arches, or those whose Rise is less than the Half Span.

1407. For the purpose of arriving at just conclusions relative to surbased arches, three models were made of the same thicknesses and diameters, with a rise of 35 lines, and in form elliptical, cassinoidal, and cycloidal. We however do not think it necessary, from the similarity of application of the rules, to give more than one example, which is that of a semi-ellipse (*fig.* 577.), in which, as before, the formula is

$$x = \sqrt{2p + \frac{2pd - 2mc}{a} + \frac{bb}{aa}} - \frac{b}{a}.$$

The lines described in the foregoing examples being drawn, we have

$$KL = 45 \cdot 5$$
$$iK = 8 \cdot 5.$$

IT, represented by d in the formula, - - = 24·84
MK - - = 14·66
$mL \times AB$ representing the thrust (37×9) gives the value of p - - - - = 333·00
$2p$ therefore - = 666·00
TI, represented by d, being 24·84, we have $2pd$ - - - = 16543·44
m, which is $KM \times AB$, will be $14 \cdot 66 \times 9$, which gives - - = 131·94
c, representing iK, being 8·5, $2mc$ - - - = 2242·94
b, which expresses the sum of the vertical efforts $m + n (39 \cdot 5 \times 9)$ - = 355·50
a, being always 120, $\frac{b}{a} = \frac{355 \cdot 5}{120}$ is - - - - - = 2·96
Lastly, $\frac{aa}{bb}$ - - - = 8·76

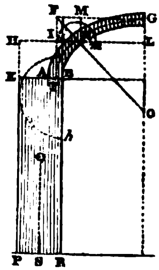


Fig. 577.

Substituting these values in the formula, we have

$$x = \sqrt{666 + \frac{16543 \cdot 44 - 2242 \cdot 94}{120} + 8 \cdot 76} - 2 \cdot 96 = 25 \cdot 22 \text{ lines, or a little less than } 25\tfrac{1}{4} \text{ lines.}$$

1408. In the model it was found that a thickness of 26 lines was necessary for the pier, and the lower voussoirs were connected with it by a cementing medium. Without which precaution the thickness of a pier required was little more than one tenth of the opening. Taking the square root of double the thrust, that is, of 666, we have 25·81, about the same dimension that the graphical construction gives. The experiments, as well as the application of the rules, require the following remarks for the use of the practical architect.

1409. I. The cassinoid, of the three curves just mentioned, is that which includes the greatest area, but it causes the greatest thrust. When the distance between the intrados and the extrados is equal in all parts, it will only stand, supposing the piers immoveable, as long as its thickness is less than one ninth part of the opening.

1410. II. The cycloid, which includes the smallest area, exerts the least thrust, but it can be usefully employed only when the proportion of the width to the height is as 22 to 7 in surbased arches, and in surmounted arches as 14 to 11. The smallest thickness with which these arches can be executed, so as to be capable of standing of themselves, is a little more than one eighteenth of the opening, as in the case of semicircular arches.

1411. III. The ellipsis, whose curvature is a mean between the first and second, serves equally well for all conditions of height, though it exerts more thrust than the last-mentioned and less than the cassinoid.

1412. It is here necessary to remark, that too thin an arch, whose voussoirs are equal in depth, may fall, even supposing the abutments immoveable, and especially when surbased;

because, when once the parts are displaced, the force of the superior parts may lift up the lower parts without disturbing the abutments.

Raking Arches.

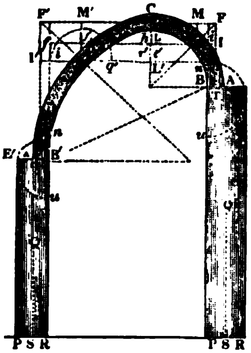


Fig. 578.

1413. Let ACA′ (*fig.* 578.) be the model of a raking arch of the same diameter and thickness as the preceding example, the voussoirs of equal thickness, and the piers of different heights, the lowest being 10 inches or 120 lines in height, and the other $14\frac{1}{2}$ inches or 174 lines. The tangent at the summit is supposed parallel to the raking lines that connect the springing.

1414. This arch being composed of two different ones, the mean circumference on each must be traced, and each has its separate set of lines, as in the preceding examples; the horizontal line KL of the smaller arch is produced to meet the mean circumference of the other in S, and the interior line of its pier in g.

1415. The part KLS represents the horizontal force of the part of the arch KGS, common to the two semi-arches; so that if a joint be supposed at S, the part LK represents the effort acting against the lower part of the smaller arch, and LS that against the lower part of the larger arch. These parts resist the respective efforts as follows: the small arch with the force represented by iK, and the greater one with the force represented by gS. But as gS is greater than LS, transfer LS from g to f to obtain the difference fS, which will show how much LS must be increased to resist the effort of the larger half arch; that is, the effort of the smaller one should be equal to Lf; but as this last requires for sustaining itself that the larger one should act against it with an effort equal to KL, this will be the difference of the opposite effort, which causes the thrust against the lower part of the smaller arch and the pier from whence it springs. Hence, transferring fL from L to q, taking the half of iq and transferring it from L to h, the part hK multiplied by the thickness AB will be the expression for the thrust represented by p in the formula

$$x = \sqrt{2p + \frac{2pd - 2mc}{a} + \frac{bb}{aa}} - \frac{b}{a}.$$

Having found $h\text{K} = 30\frac{1}{2}$ and $\text{AB} = 9$, we have for the value of p $30\frac{1}{2} \times 9 = 274\frac{1}{2}$, and for that of $2p - 549$, d which represents IT, being $29\frac{1}{2}$, $2pd = 16195\frac{1}{2}$. In $2mc$; m, which represents $\text{MK} \times \text{AB}$, will be $12\frac{1}{3} \times 9 = 111$, and $2m = 222$.

c, which represents iK, being 8, we have $2mc = 222 \times 8 = 1776$.

The height of the pier represented by a being 174, we have

$\frac{2pd - 2mc}{a} = \frac{16195\frac{1}{2} - 1776}{174}$ - - - - - - - $= 82{\cdot}81$

The vertical effort represented by b, or $\text{TF} \times \text{AB}$, will be $41\frac{2}{3} \times 9 = 375$,

and $\frac{b}{a} = \frac{375}{174}$ becomes - - - - - - $= 2{\cdot}15$

and $\frac{bb}{aa}$ - - - $= 4{\cdot}64$

Substituting these values in the formula, we have

$x = \sqrt{549 + 82{\cdot}81} + 4{\cdot}64 - 2{\cdot}16 = 23{\cdot}08$ for the thickness of the greater pier from which the smaller semi-arch springs.

For the half of the greater arch, having produced the horizontal line IK′L′, make K′r equal to VL′, and bisect rL′ in t; the line K′t represents the effort of the smaller against the greater arch, which resists it with a force shown by i'K′: thus making K′q' equal to i'K, the effort of the thrust will be indicated by $q't \times \text{AB}$, whose value p in the formula will be

$20 \times 9 = 180$, and $2p$ - - - - $= 360$
d, which is TI, being $69\frac{2}{3}$, $2pd$ will - - $= 25080$
In $2mc$, m being $26 \times 9 = 234$, and c being $23\frac{1}{6}$, $2mc$ $= 10842$
a, the height of the smaller pier - - - $= 120$
We have $\frac{2pd - 2mc}{a} = \frac{25080 - 10842}{120}$, which becomes - $= 118{\cdot}65$
b, which is $\text{TF} \times \text{AB}$, will be $95\frac{2}{3} \times 9$ - - $= 861$
$\frac{b}{a} = \frac{861}{120} = 7{\cdot}175$, and $\frac{bb}{aa}$ - - - - $= 51{\cdot}48$

Substituting these values in the formula, we have

$x = \sqrt{360 + 118{\cdot}65 + 51{\cdot}48} - 7{\cdot}175 = 15{\cdot}855$ lines for the thickness of the smaller pier.

Taking the square root of double the thrust, we should have for the larger pier 23·44 lines, and for the smaller one 19 lines. In the geometrical operation, for the larger pier make B*u* equal to *h*K and B*n* equal to 2AB; then upon *un* as a diameter describe a semicircle cutting the horizontal line BA produced in E. BE will be the thickness of the pier, and will be found to be 23¼ lines. For the smaller pier make B′*u*′ equal to *q*′*t* and B′*n*′ equal to 2A′B′. Then the semicircumference described upon *un* as a diameter will give 19 lines for the thickness.

1416. By the experiments on the model 22 lines was found to be the thickness necessary for the larger pier, and 18 lines for the smaller one.

Arch with a level Extrados.

1417. The model of arch *fig.* 579. is of the same opening as the last, but with a level extrados, serving as the floor of an upper story. The thickness of the keystone is 9 lines. To find the place of fracture or of the greatest effort; having raised from the point B the vertical BF till it meets the line of the extrados, draw the secant FO cutting the interior circumference at the point K, and through this point draw the horizontal IKL and the vertical HKM

The part CDKF will be that which causes the thrust, and its effort is represented by

KL, which will be found - - - = 35·14
FH = IK, which is *c* in the formula, will be - = 18·86
The arch or circumference KD of 10° 36′ - = 38·28
The arch KB - - - - = 46·57
The arch DKB - - - - = 84·85
KH, represented by *d*, - - - = 22
The vertical HKM - - - - = 63
The height of the pier, represented by *a* in the formula, = 183

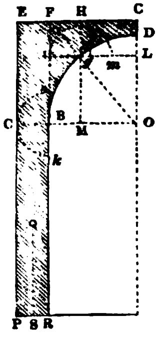


Fig. 579.

The area of the upper voussoir FKCD = 667·44; but as the load of the haunches is borne by the inferior voussoir, we must subtract the triangle $\text{FKH} = \frac{18{\cdot}26 \times 22}{2} = 207{\cdot}46$. The remainder 459·98 multiplied by KL and divided by the arc KD, that is, $\frac{459{\cdot}98 \times 35{\cdot}14}{38{\cdot}28} =$ 422·24, represents the effort of the upper part.

1418. That of the lower part, represented by $\frac{\text{FBKH} \times \text{IK}}{\text{KB}}$, is $\frac{651{\cdot}07 \times 18{\cdot}86}{46.57}$, which becomes 263·67. The difference of the two efforts = 158·57 will express the thrust or *p* of the formula, and we have $2p = 317{\cdot}14$.

1419. The piers being supposed to be continued up to the line EC of the extrados will be greater than the arm of the lever of the thrust which acts at the point K. Thus the expression of the arm of the lever, instead of being $a + d$, as in the preceding examples, will be $a - d$, and the sign of $\frac{2pd}{a}$ must be changed. In numbers, $\frac{317{\cdot}14 \times 22}{183} = 38{\cdot}12$; therefore, in the formula, $+\frac{2pd}{a}$ becomes $-38{\cdot}12$.

1420. In the preceding examples, $2mc$, which represented double the vertical effort of the superior voussoir multiplied by the arm of its lever, becomes nothing, because it is comprised in the addition made to the lower voussoir; so that the formula now is

$$x = \sqrt{2p - \frac{2pd}{a} + \frac{bb}{aa}} - \frac{b}{a}.$$

b, then, which always expresses the vertical effort of the half arch, is therefore

$$\frac{1111{\cdot}05 \times 63}{84{\cdot}85} = 824{\cdot}94\text{; and for } \frac{b}{a} \text{ we have } \frac{824{\cdot}94}{183} = 4{\cdot}5\text{, and } \frac{bb}{aa} = 20{\cdot}25.$$

Substituting these values in the last formula, we shall have

$$x = \sqrt{319{\cdot}14 - 38{\cdot}12 + 20{\cdot}25} - 4{\cdot}5 = 12{\cdot}88 \text{ lines.}$$

Experiment gives 14 lines as the least thickness that can be relied on.

To find the thickness by the geometrical method, make K*m* equal to IK and B*h* equal to *m*L, B*n* to double CD, and upon *nh* as a diameter describe the semicircumference cutting the horizontal line OB produced in A: then BA = 17¼ lines is the thickness sought.

1421. Rondelet proves the preceding results by using the centres of gravity, and makes the result of the operation 12·74 instead of 12·80, as first found. But the difficulty of finding the centres of gravity of the different parts is troublesome; and with such a concurrence of results we do not think it necessary to enter into the detail of the operation.

A different Application of the preceding Example.

1422. The model (*fig.* 580.) is an arch similar to that of the preceding example, having a story above it formed by two walls, whose height is 100, and the whole covered by a timber roof. The object of the investigation is to ascertain what change may be made in the thickness of the piers which are strengthened in their resistance by the additional weight upon them.

1423. The simplest method of proceeding is to consider the upper walls as prolongations of the piers.

1424. In the model the walls were made of plaster, and their weight was thus reduced to ¾ of what they would have been if of the stone used for the models hitherto described. The roof weighed 12 ounces. We shall therefore have that 100, which in stone would have represented the weight of the walls, from the difference in weight of the plaster, reduced to 75. In respect of the roof, which weighed 12 ounces, having found by experiment that it was equal to an area of 576 lines of the stone, both being reduced to equal thicknesses, we have 12 ounces, equal to an area of 13·82 whose half 6·91 must be added to that of the vertical efforts represented by b in $\frac{b}{a}$ and $\frac{bb}{aa}$. Changing these terms into $\frac{h}{a}$ and $\frac{hh}{aa}$, the formula becomes

$$x = \sqrt{2p - \frac{2pd}{a} + \frac{hh}{aa}} - \frac{h}{a}.$$

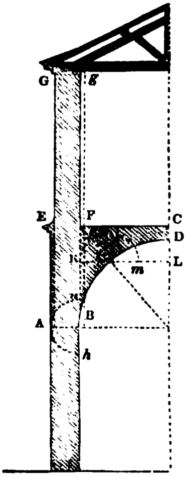


Fig. 580.

The height of the piers or a in the formula $= 183 + 75 = 258$.

p does not change its value, therefore $2p$ (as in the preceding example) $= 265 \cdot 86$.

d, the difference between the height of the pier and the arm of the lever, will $= 75$.

Hence, $\frac{2pd}{a} = \frac{565 \cdot 25 \times 75}{258} = 77 \cdot 28$.

h, becomes $750 \cdot 69 + 691 = 1441 \cdot 69$.

And $\frac{h}{a} = \frac{1441 \cdot 69}{358} - 5 \cdot 58$.

Again, $\frac{hh}{aa} = 31 \cdot 22$.

Substituting these values in the formula, we shall have

$$x = \sqrt{265 \cdot 86 - 77 \cdot 28 + 31 \cdot 22} - 5 \cdot 58 = 9 \cdot 15.$$

In the model a thickness of 11 lines was found sufficient to resist the thrust, and taking the root of double the thrust the result is 13 lines.

1425. By the geometrical method, given in the last, taking from the result 17¼ lines, there found, the value of $\frac{h}{a}$, that is, 5·58, the remainder 11⅔ lines is the thickness sought.

1426. It may be here observed, that in carrying up the walls above, if they are set back from the vertical BF in *hf*, the model required their thickness to be only 6 lines, because this species of false bearing, if indeed it can be so called, increases the resistance of the piers.

This was a practice constantly resorted to in Gothic architecture, as well as that of springing pointed arches from corbels, for the purpose of avoiding extra thickness in the walls or piers.

Another Application of the Principles to a differently constructed Arch.

1427. The model (*fig.* 581.) represents an arch of 11 voussoirs whereof 10 are with crossettes or elbows, which give them a bearing on the adjoining horizontal courses; the eleventh being the keystone. The opening is 9 inches or 108 lines, as in the preceding examples.

1428. Having drawn the lines BF, FC, the secant FO, and the horizontal line IKL, independent of the five courses above the line FC of the extrados, we have

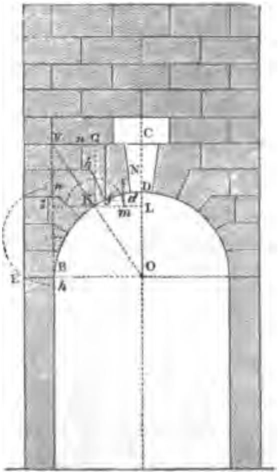


Fig. 581.

KL = 30·73
IK = 23·27
OC = BF = 78·00
The arc KD = 32·70
The arc KB = 52·15
KG = 33·59
a, the height of the pier, = 198·00.

The area KFCL of the upper part of the arch will be 1223·10, from which subtracting that of the triangle FKG, which is 590·82, the remainder 832·28 being multiplied by 30·73 and divided by 32·7 makes the effort of this part 782·44.

1429. The area of the lower part is 697·95, to which adding the triangle FKG = 390·82, we have 1088·77, which multiplied by 23·27 and divided by 52·15, gives 485·82 for its effort. The expression of the thrust, represented by p in the formula,

$x = \sqrt{2p - \frac{2pd}{a} + \frac{bb}{aa}} - \frac{b}{a}$, being equal to the difference of these two efforts,
will be 296·62, and twice p - - = 593·24
d, representing KG, being - - = 33·59
we have $2pd = 19926·93$, and $\frac{2pd}{a}$ - = 100·64

b, representing the sum of the efforts of the semi-arch, will be $\frac{1921 \times 78}{85} = 1762·03$
$\frac{b}{a} = \frac{1762·8}{198} = 8·9$ and $\frac{bb}{aa}$ - - - = 79·21

Substituting these values in the formula, we have the equation

$$x = \sqrt{593·24 - 100·64 + 79·21} - 8·9 = 15·01.$$

By taking double the square root of the thrust the result is 23·91, a thickness evidently too great, because the sum of the vertical efforts, which are therein neglected, is considerable.

1430. The geometrical method gives 19 lines. The least thickness of the piers from actual experiment was 16 lines.

1431. Rondelet gives a proof of the method by means of the centres of gravity, as in some of the preceding examples, from which he obtains a result of only 13·26 for the thickness of the piers.

Consideration of an Arch whose Voussoirs increase towards the Springing.

1432. The model (*fig.* 582.) has an extrados of segmental form not concentric with its intrados, so that its thickness increases from the crown to the springing. The opening is the same as before, namely, 9 inches, or 108 lines. The thickness at the vertex is 4 lines, towards the middle of the haunches $7\frac{1}{4}$ lines, and at the springing $14\frac{1}{4}$ lines. The centre of the line of the extrados is one sixth part of the chord AO below the centre of the intrados; so that

The radius DN = 68·05
KL = 38·18
IK = 15·82
The arc BK = KC = 42·43

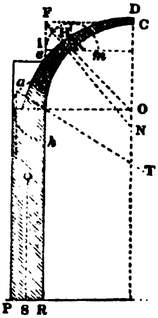


Fig. 582.

1433. The area KHDC of the upper part of the arch is 258·75, that of the lower part BAHK 486·5; hence the effort of the upper part is represented by the expression $\frac{258·75 \times 38·18}{42·43} = 232·47$.

1434. The half segment ABe being supposed to be united to the pier; BeHK, whose area is 178, is the only part that can balance the upper effort; its expression will be $\frac{178 \times 15·82}{42·43} = 66·24$. The difference of the two efforts 166·23 will be the expression of the thrust represented by p in the formula

$$x = \sqrt{2p + \frac{2pd - 2mc}{a} + \frac{bb}{aa}} - \frac{b}{a}$$

Thus $2p$ - - - = 332·46
IB = KL, indicated by d, - - - = 38·18
Which makes the value of $2pd$ - - - = 12693·92
The vertical effort of the upper part indicated by $m = \frac{258·75 \times 1582}{42·43}$ = 96·30
and for $2pm$ - = 192·60
The value of c being 15·82, we have $2mc$ - - = 3046·50

The height of the piers being still 120, we have

$$\frac{2pd-2mc}{a}=\frac{12693{\cdot}92-3046{\cdot}5}{120} \quad - \quad - \quad = \quad 80{\cdot}39$$

b, which indicates the vertical effort of the half arch represented by FB, will be $\frac{745{\cdot}26\times 54}{84{\cdot}85}$ - - = 473·48

$$\frac{b}{a}=\frac{473{\cdot}48}{120} \quad - \quad - \quad - \quad - \quad = \quad 3{\cdot}95$$

$$\text{and } \frac{bb}{aa} \quad - \quad = \quad 15{\cdot}56$$

These values being substituted in the formula, will give

$$x=\sqrt{332{\cdot}46+80{\cdot}39+15{\cdot}56}-3{\cdot}95=16{\cdot}74 \text{ lines.}$$

1435. The smallest thickness of pier that would support the arch in the model was 17½ lines.

1436. With the geometrical method, instead of the double of CD, make Bh double the mean thickness HK, and Bn equal to mL, and on nh as a diameter describe the semicircumference cutting OB produced in E; then EB = 18¼ lines will be the thickness sought.

1437. If the pier is continued up to the point e where the thickness of the arch is disengaged from the pier, the height of the pier represented in the formula by a will be 151·5 instead of 120, and the difference b, instead of being $\frac{745{\cdot}26\times 54}{85}$, will be only $\frac{436{\cdot}75\times 54}{85}$ = 277·46.

1438. d, expressed by Ie, will be 6·5, all the other values remaining the same as in the preceding article, the equation is

$$x=\sqrt{332{\cdot}46-5{\cdot}71+4}-2=16{\cdot}21.$$

1439. Using the method by means of the centres of gravity, Rondelet found the result for the thickness of the piers to be 15·84. So that there is no great variation in the different results.

1440. In the preceding examples arches have been considered rather as arcades standing on piers than as vaults supported by walls of a certain length. We are now about to consider them in this last respect, and as serving to cover the space enclosed by the walls.

In respect of cylindrical arches supported by parallel walls, it is manifest that the resistance they present has no relation to their length; for if we suppose the length of the vault divided into an infinite number of pieces, as C, D, E, &c. (*fig.* 584. No. 2.), we shall find for each of these pieces the same thickness of pier, so that all the piers together would form a wall of the same thickness. For this reason the surfaces only of the arches and piers have been hitherto considered, that is, as profiles or sections of an arch of any given length. Consequently it may be said that the thickness of wall found for the profile in the section of an arch would serve for the arch continued in length infinitely, supposing such walls isolated and not terminated or rather filled by other walls at their ends. When cylindrical walls are terminated by walls at their extremities, after the manner of gable ends, it is not difficult to imagine that the less distant these walls are the more they add stability to those of the arch. In this case may be applied a rule which we shall hereafter mention more at length under the following section on Walls.

1441. If in any of the examples (*fig.* 582. for instance) PR be produced indefinitely to the right, and from R on the line so produced the length of the wall supporting the arch be set out, and if from the extremity of such line another be drawn, as TB produced through B, indefinitely towards a, and Ba be made equal to the thickness of the pier first found, a vertical line let fall from a will determine the thickness sought. When arches are connected with these cross walls, the effect of the thrust may be much diminished if they are not very distant. If there be any openings in the walls, double the length of them must be added to that of the wall as well as of any that may be introduced in the gable wall.

1442. *Fig.* 583. represents the mode in which an arch fails when the piers are not of sufficient strength to resist the thrust: they open on the lower part of the summit at DM and on the upper part of the haunches at HN; from which we may infer that the thrust of an arch may be destroyed by cramping the under side of the voussoirs near the summit and the upper side of those towards the middle of the haunches; and this method is greatly preferable to chains or iron bars on the extrados, because these have no effect in preventing a failure on the underside. Chains at the springing will not prevent failure in arches whose voussoirs are of equal depth but that too small, inasmuch as there is no counteraction from them against the bulging

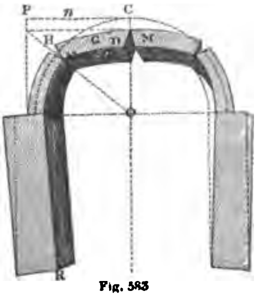


Fig. 583

that takes place at the haunches, like a hoop loaded when its ends are fixed. The most advantageous position for a chain to oppose the effort of an arch is to let it pass through the point K where the efforts meet. PC is the tangent before failure, and O the centre; R being the inner point of the pier.

OF COMPOUND VAULTING.

1443. M. Frezier, in speaking of the thrust of this sort of arches, proposes, in order to find the thickness of the piers which will support them, to find by the ordinary manner the thickness suitable to each part of the cylindrical arch BN, BK (No. 3. *fig.* 584.) by which the groin is formed, making BE the thickness suitable to the arch BN, and BF that which the arch BK requires; the pier BEHF would thus be able to resist the thrust of the quarter arch OKBN. According to this method we should find the bay of a groined arch 9 inches opening would not require piers more than 21 lines square and 120 lines high; but experience proves that a similar arch will scarcely stand with piers 44 lines square, the area of whose bases are four times greater than that proposed by M. Frezier.

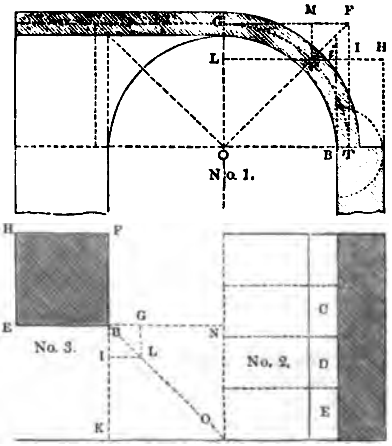


Fig. 584.

Method for groined Vaulting.

1444. The model in this case (see the last figure) is 9 inches in the opening, voussoirs equally thick, being 9 lines, standing upon four piers 10 inches or 120 lines high.

1445. The groin is formed by two cylindrical arches of the same diameter crossing at right angles, as represented in No. 3. of the figure. The four portions of the vault being similar, the calculation for one pier will be sufficient.

1446. On the profile No. 1. of the figure describe the mean circumference TKG, draw the tangents FT and FG, and the secant FO and the horizontal line IKL. Draw the vertical B*i*, and NG and KI on the plan (No. 3.) equal to KL.

1447. In the foregoing examples for arches and cylindrical vaulting there has been no necessity to consider more than the surface of the profiles, which are constantly the same throughout their length; but the species of vault of which we are now treating being composed of triangular gores whose profile changes at every point, we shall be obliged to use the cubes instead of the areas of squares, and to substitute surfaces for lines. Thus in viewing the triangular part KBO, the sum of the horizontal efforts of the upper part of this portion of the vault, represented in the profile by KL, will be represented in plan by the trapezium KILO.

1448. The sum of those of the lower part *i*K in the profile is represented in plan by BIL. The thrust is expressed by the difference of the area of the trapezium and of the triangle multiplied by the thickness of the vault; thus, KB and KO of the plan being 54, the superficies of the triangle BKO will be $54 \times 27 = 1458$; the part BK of the plan being equal to IL, and B*t* to *i*K of the profile $= 12\frac{2}{14}$, the area of the triangle BIL, indicating the sum of the horizontal efforts of the upper part, will be $12\frac{2}{14} \times 6\frac{2}{28} = 79\frac{13}{14}$.

1449. We obtain the area of the trapezium KILO by subtracting that of the small triangle BIL from the greater triangle BKO, that is, $79\frac{13}{14}$ from 1458; the remainder $1378\frac{1}{14}$ gives the horizontal effort of the upper part; lastly, subtracting $79\frac{13}{14}$ from $1378\frac{1}{14}$, the remainder $1298\frac{2}{14}$ will be the expression of the thrust whose value is found by multiplying $1298\frac{2}{14}$ by $9 = 11683\frac{2}{7}$, which is the p of the formula.

$$x = \sqrt{2p + \frac{2pd - 2mc}{a} + \frac{bb}{aa}} - \frac{b}{a}.$$

Letting a always stand for the height, and d for TI of the profile, the arm of the lever of the thrust will, as before, be $a + d$, and its algebraic expression be $pa + pd$.

1450. The pier resists this effort by its cube multiplied by the arm of its lever. If the lines KB and OB of the triangle BKO, (which represents the projection of that part of the vault for which we are calculating) be produced, it will be seen that the base of the pier to resist the thrust will be represented by the opposite triangle BHF, which is rectangular and isosceles; therefore, letting x represent its side BF, the area of the triangle will be expressed by $\frac{xx}{2}$, the height of the pier being a, its cube will be $\frac{axx}{2}$. The arm of the lever of this pier will be determined by the distance of the vertical let fall from its centre of gravity on the line $HF = \frac{x}{3}$, which gives for the pier's resistance $\frac{axxx}{6}$.

1451. This resistance will be increased by the vertical effort of each part of the vault multiplied by the arm of its lever.

That of the upper part will be expressed by its cube multiplied by the vertical KM, and the product divided by the mean arc KG.

The cube of this part will be equal to the mean area; that is, the arc KG multiplied by the thickness of the vault.

1452. To obtain the mean area, multiply KG less KM by the length GO taken on the plan. The length of the arc KG being 46 and KM $17\frac{1}{7}$, we shall have $KG - KM = 28\frac{6}{7}$; GO being 54, the mean area will be $28\frac{6}{7} \times 54 = 1558$. This area multiplied by 9, the thickness of the vault, makes the cube of the upper part $14024\frac{4}{7}$, which multiplied by $KM = 17\frac{1}{7}$ and divided by the arc $KG = 46$, makes $5226\frac{1}{2}$ the value of the vertical effort of the part of the arch m in the formula; and the arm of its lever is $IK + iH$.

1453. IK being $= c$ and $iH = x$, its expression will be $mx + mc$.

The vertical effort of the lower part will be represented by its cube multiplied by TI, and the product divided by the length of the arc TK.

This cube will be found by multiplying the mean area by the thickness of the vault. The area being equal to the arc $TK - TI \times GO$, that is, $46 - 41\frac{5}{14} \times 54 = 250\frac{5}{7}$ for the mean area and $250\frac{5}{7} \times 9 = 2256\frac{3}{7}$ for the cube of the lower part of the vault. This cube multiplied by TI and divided by the arc TK gives $\frac{2256\frac{3}{7} \times 41\frac{5}{14}}{6} = 2028\frac{3}{4}$ for the value of the vertical effort of the part n of the formula. And it is to be observed, that this effort acting against the point B, the arm BF of the lever will be x and its expression nx.

1454. Bringing together all these algebraic values we obtain the equation $pa + pd = \frac{ax^3}{6} + mx + mc + nx$; and making $m + n$; which multiplies $x = b$, we have $pa + pd = \frac{ax^3}{6} + bx + mc$. Transferring mc to the other side of the equation, we have $pa + pd - mc = \frac{ax^3}{6} + bx$. Lastly, multiplying all the terms of the equation by $\frac{6}{a}$ for the purpose of eliminating x^3, we shall have instead of the preceding formula $6p + \frac{6pd - 6mc}{a} = x^3 + \frac{6bx}{a}$, which is an equation of the third degree, whose second term is wanting. For more easily resolving this equation, let us find the value of $6p + \frac{6pd - 6mc}{a}$ and that of $\frac{6b}{a}$, by which x is multiplied in the second part of the equation.

p being $11683\frac{1}{7}$, $6p$ will be - - - - $= 70069\frac{6}{7}$
d being $41\frac{5}{14}$, $6pd$ will be - - - - $= 2899124\frac{3}{7}$
m being $5226\frac{1}{2}$, $6mc$ - - - - - $= 537593\frac{1}{7}$

Thus $\frac{6pd - 6mc}{a} = \frac{2361537\frac{2}{7}}{120} = 19679\frac{5}{14}$, and $6p + \frac{6pd - 6mc}{a} = 89779\frac{1}{7}$, which we will call g, for the purpose of simplifying the remainder of the calculation.

b, which represents $m + n$, will be $5226\frac{1}{2} + 2038\frac{3}{4} = 7255\frac{1}{4}$, and $\frac{6b}{a} = \frac{43534}{120} = 362\frac{3}{4}$; this we will call f; so that instead of the equation $6p + \frac{6pd - 6mc}{a} = x^3 + \frac{6bx}{a}$, we have $g = x^3 + fx$, which is thus to be resolved (Bossut, *Elemens d'Algebra*): —

$$x = \sqrt[3]{\frac{g}{2} + \sqrt[2]{\frac{gg}{4} + \frac{f^3}{27}}} + \sqrt[3]{\frac{g}{2} - \sqrt[2]{\frac{gg}{4} + \frac{f^3}{27}}}.$$

Substituting in this formula the values of g and f, we have

$$x = \sqrt[3]{44889\frac{4}{7} + \sqrt[2]{2015073623 + 1767902}} + \sqrt[3]{44889\frac{4}{7} - \sqrt[2]{2015073623 + 1767902}}$$

$= \sqrt[3]{44889\frac{4}{7} + 44909\frac{6}{7}} + \sqrt[3]{44889\frac{4}{7} - 44909\frac{6}{7}}$, from which extracting the cube roots, we have $x = 44\frac{3}{4} - 2\frac{3}{4} = 42$ for the length BF of one of the sides of the triangular pier BAF; the other FA may be determined by the production of the diagonal or line of groin OB.

The part of the pier answering to the part of the vault BNO is determined by drawing from the points B and A the parallels BM and MA to FA and FB. These two triangles will form a square base, each of whose sides will be 42 lines, answering to one quarter of the vault KBNO; thus, to resist the thrust of the vault, four piers, each 42 lines thick, are necessary.

1455. The above result corresponds in a singular manner with the experiments which were made by Rondelet, from which he deduced a thickness of $43\frac{1}{4}$ lines. In his investigation of the example by means of the centres of gravity 40·53 lines was the result. Our limits prevent further consideration by other examples; we will merely therefore observe, that the method above given seems to be a safe guide to the architect. In the case of oblong arches, the results must be obtained for each side.

1456. In the case of groinings composed of many bays, the chief care necessary is in the external piers, which will require especially to be of sufficient thickness. Those in the middle, being counterbalanced all round, have only to bear the weights of their respective arches, for which purpose they must have a proportional area and be of such stone as the weight will not crush. But it ought to be recollected that in good construction the area of the points of support should be so distributed as to establish for each a sufficient strength, because a single weak point will often endanger the whole fabric.

1457. In practice, a readier method will be wanting than that which has been just discussed; we therefore subjoin one which agrees well enough with theory and experiment, and it is as follows. Let ABCD (*fig.* 585. No. 1.) be the space to be covered by a groined vault supported in the centre by the pier E. Dividing each side into two equal parts, draw the lines HI, FG crossing each other in the centre K′, K″, and the diagonals AE, EB, EC, ED and HF, HG, IF, IG crossing each other in the points K, K′, K″, K‴. In No. 2. draw the pier its half height to the level of the springing, which half height transfer from E to K and divide EK into twelve parts. One of these parts will be a half diagonal of the pier. For the intermediate piers H, F, I, G, after finding the diagonals of the half piers, produce them outwards to double their projection within, so that altogether their thickness may be once and a half their width. For the angular piers this method will give an area of base 1⅓ times greater, which will enable them to resist the thrust they have to sustain.

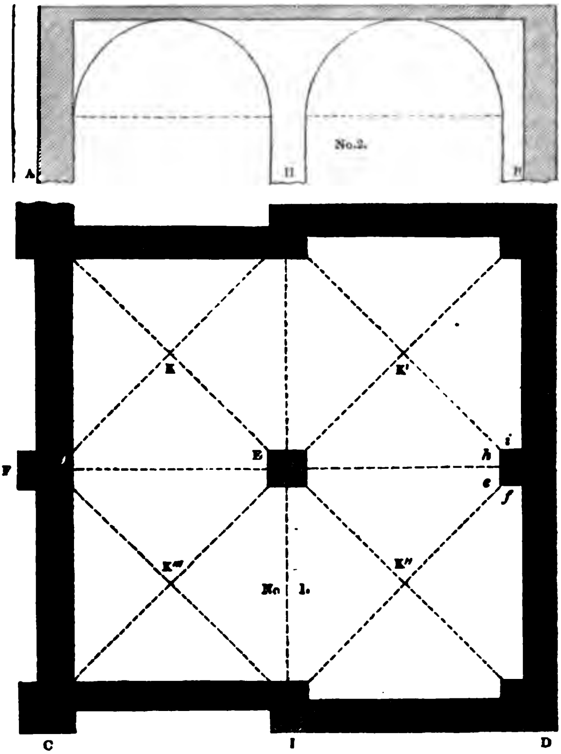


Fig. 585.

1458. When the width of the space to be vaulted is to be divided into three bays, and that of the middle is required to be raised above those of the other two, as in the case of churches with side aisles, the bases of the points of support may be determined in two ways. That most used, which is borrowed from the Gothic examples, is to give to the areas of the bases of the points of support merely the extent necessary to bear the load they are to receive, by throwing the strain of the thrust upon the external piers by means of flying buttresses, and giving to their points of support a position and surface of base capable of effectual resistance.

1459. The most simple method derived from the principles of the theory for the first case is as follows: —

Having laid down the plan of the two bays which fall upon the same pier (*fig.* 586. No. 1.), take one half of the sum of the two semi-diagonals AD, AE, to which add one half of the height of the point of support, and taking a twelfth part of the whole as a radius, describe a circle, and it will indicate the surface sought of the base of the point of support. If it be not circular it must be circumscribed with the form that may be required, so as rather to increase than diminish its solidity. For the exterior point of support B let a rectangle be formed, having for its width the side of a square inscribed in the preceding circle, and in length double.

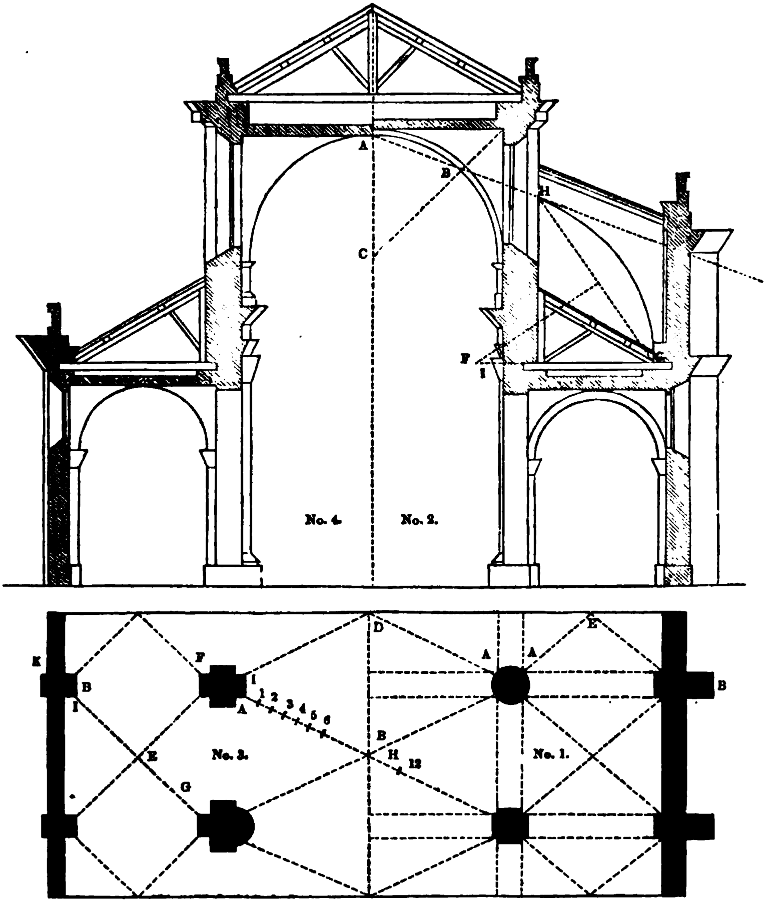


Fig. 586.

1460. Above the roofs of the sides a flying buttress may be carried up, whose pier may be raised on that below, set back one sixth from the exterior face and sloped as much on the interior. The line of summit or tangent of this flying buttress, which should be of the single arc of a circle, will be determined by the chord of the arc of the upper part of the vault produced indefinitely. To find the centre, draw the chord GH (No. 2.), on the middle of which raise a perpendicular, which will cut the horizontal line GF in the point I, which will be the centre of the arc. These raking arches may be connected by other return arches, which may bear a floor above with a support, upon which a passage round the building may be made, and this may be concealed by an attic order outside.

1461. In the second case, the base of a pier must be found capable of resisting the effort of the great middle vault of the nave, by taking as the height of its pier the rise from its springing above the side vaults No. 3., and laying the half of this height from B to H on the plan No. 2. Then having divided IH into twelve equal parts, make IA equal to one of them and AF equal to two. The rectangle made upon the diagonal FI shows the area of the interior pier, to which are to be added, to the right and left, projections to receive the arches of the sides. The length FD is to be divided into six equal parts, whereof two are for the projection of the pilaster or interior half column, upon which the entablature is profiled, three for the thickness of the wall, and one for the pilaster on the side aisles, whose prolongation will form a counterfort above the lower sides.

1462. For the external pier B, as before, one half the height to the springing must be transferred from EG, and $\frac{1}{12}$ of BG from B to L; lastly, $\frac{2}{12}$ from B to K: the rectangle formed upon the diagonal KL is equal to the area of the pier. We must add, as for that in front, the projections to receive the arches or windows, as shown in No. 2.

1463. As long as the intervals between the piers are filled in with a wall, if that be placed flush with the outside, the piers will form pilasters inwards (see *fig.* 585.), as *ihef*, whose projection *ef* is equal to one half of the face *he*; this wall ought to have a thickness equal to *he*; but if it is brought to the inner line of the face of the piers, they need be only two thirds of the thickness; so that the piers will form counterforts on the exterior. In conclusion, knowing the effort of the thrust, the calculations will not be attended with difficulty in providing against it by adequate means of resistance.

ON THE MODEL OF A COVED VAULT.

1464. The model (*fig.* 587. Nos. 1. and 2.) is a square on the plan, each of whose sides is 9 inches internal measure, enclosed by a wall 10 inches high to the springing of the vault, which is semicircular in form, and the voussoirs throughout 9 inches thick. It is divided into seven parts at the points of greatest effort, as shown in Nos. 1. and 2. in the plan and section. On one of the sides of the first is supposed to be traced the mean circumference TKG, the tangents FT, FG, the secant FO, the horizontal line IKL, and the verticals B*i* and MK. We may now therefore consider this vault as four triangular pieces of cylindrical arches, each resting throughout the length of their base on one of the walls which forms the sides of the square. As the portions of arches or vaults are equal, it is only necessary to take one of them for an example.

1465. In the last example, cubes are taken instead of the surfaces, and surfaces instead of lines. Thus expressing the length of the wall by f, its height by a, and its thickness by x; the arm of the lever being always $\frac{x}{2}$, its resistance is expressed by $afx\frac{x}{2}$.

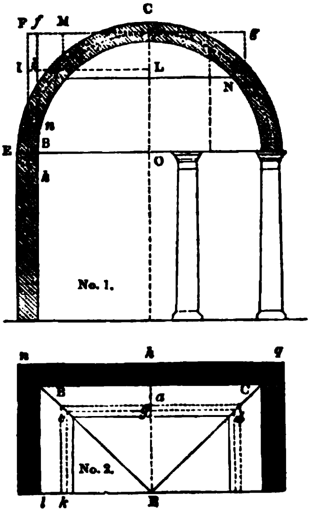


Fig. 587.

Making the thrust - - - - $=p$
EP = TI = KL = KV - - - - $=d$
PH - - - - - - $=a+d$
The sum of the vertical efforts of the upper part - $=m$
That of the lower parts - - - - $=n$
The part IK of the horizontal line - - - $=c$
TB = half the thickness of the arch - - - $=e$
The arm of the lever will be - - - $=c+x$
TE - - - - - - $=x-e$,

The equation is $pa+pd=\frac{afx^2}{2}+(m+n)x-ne+mc$;

and making $m+n=b$,

$$\frac{afx^2}{2}+bx=pa+pa+ne-mc;$$

$$\text{Whence } x=\sqrt{\frac{2p}{f}+\frac{2pd+2me-2mc}{af}+\frac{b^2}{a^2f^2}}-\frac{b}{af}$$

1466. If, however, we suppose the effort to take place at the point B, a supposition hitherto made in the formulæ, we have $e=o$, and the value of x becomes

$$x=\sqrt{\frac{2p}{f}+\frac{2pd-2mc}{af}+\frac{b^2}{a^2f^2}}-\frac{b}{af}$$

1467. The horizontal effort of the upper part, represented by the line KL, will be expressed by the triangle *e*E*d* of the plan; that of the lower part *i*K in the section will be expressed by the trapezium *e*BC*d* on the plan.

1468. The plan of the vault being square, the base *ed* will be double EG = KL of the section; and the area of the triangle *e*E*d* equal to the square of KL $=41\frac{5}{14}\times 41\frac{5}{14}=1710\frac{2}{5}$.

1469. E*a* of the plan being equal to the square of 54 less the square of $41\frac{5}{14}$, that is, $1206\frac{2}{5}$, the superior effort being $1710\frac{2}{5}$, their difference is 504, which being multiplied by the thickness of the vault, or 9, is 4536 for the expression of the thrust represented by p in the formula, and for that of

$$2p=9072 \text{ and } \frac{2p}{f}=84,$$

d, which represents TI, being $41\frac{5}{14}$, $2pd=375192$.

1470. To obtain the vertical effort of the upper part of the arch represented by m, its cube must be multiplied by KM, and the product divided by the arc KG.

1471. The cube of this part is equal to the curved surface passing through the middle of its thickness multiplied by the thickness. The mean area is equal to the product of the length nq taken on the plan multiplied by KM.

mq being 117, and KM $17\frac{1}{7}$, the product expressing such mean area is $2005\frac{5}{7}$, which multiplied by 9 makes the cube $18051\frac{1}{7}$. This cube again multiplied by KM $=17\frac{1}{7}$, and divided by the length of arc KG = 46, gives 6727 for the value of m, and for $2m$ 13454; c being $12\frac{9}{14}$, $2mc=170100\frac{2}{5}$.

$$\frac{2pd-2mc}{af}=\frac{375192-170100\frac{2}{5}}{120\times 108}=15{\cdot}82.$$

b, representing the vertical effort of the half vault, will be expressed by the cube multiplied by Bf = $58\frac{1}{2}$, and divided by the mean circumference TKG = 92.

1472. To obtain the cube, the mean superficies, that is, $nq\times$ Bf or $117\times 58\frac{1}{2}$, is to be multiplied by the thickness AB = 9, which gives $6844\frac{1}{2}\times 9=61600\frac{1}{2}$.

This cube multiplied by Bf = $58\frac{1}{2}$ and divided by the mean circumference TKG = 92, that is, $61600\frac{1}{2}\times\frac{58\frac{1}{2}}{92}=39169{\cdot}88$, for the value of b, and for that of $\frac{b}{a}$, $\frac{39169{\cdot}88}{120\times 108}=3{\cdot}02$ and $\frac{bb}{aa}=9{\cdot}12$. Substituting these values in the formula,

$$x=\sqrt{\left(\frac{2p}{f}+\frac{2pd-2mc}{af}+\frac{bb}{a^2f^2}\right)}-\frac{b}{af}$$

$$\text{Hence } x=\sqrt{84+15{\cdot}82+9{\cdot}12}-3{\cdot}02=7{\cdot}41;$$

that is, a little less than $7\frac{1}{2}$ lines for the thickness of the walls, which is less than that of the vault; and shows that by giving the walls the same thickness as the vault, all the requisite solidity will be obtained. This is proved by experiments, for in the model the vault was borne equally well on walls of 9 lines in thickness divided into 8 parts, as upon 12 Doric columns whose diameter was 9 lines, four being placed at the angles and eight others under the lower part of the vault.

1473. To find the thickness of these walls by the geometrical method: Take the difference between the area of the triangle BEC and that of the triangle E*ed*, which divide by the length BC.

Thus, the area of the greater triangle being $\frac{108\times 54}{2}=2916$; that of the smaller one, $\frac{82\frac{5}{7}\times 41\frac{5}{14}}{2}=1710{\cdot}4$; their difference, 1205·6 divided by 108 = 11·16, which transfer to the profile from B to h, and make Bn equal to the thickness of the vault. Upon nh, as a diameter, describe a semicircle, which at its intersection with the horizontal line BE will determine the thickness of the vault, and be found to be 10 lines.

1474. The small thrust of this species of vaulting occurs on account of the upper part, which causes it, diminishing in volume in proportion as the horizontal effort becomes more considerable, and because the triangular form of its parts and their position give it the advantage of having the larger sides for bases; whilst, in groined vaulting, the triangular parts resting only on an angle, the weight increases as the horizontal efforts.

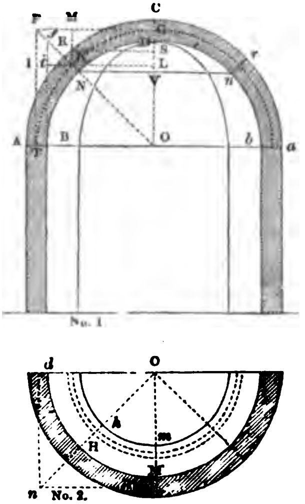
1475. Moreover, as the return sides mutually sustain each other, a half vault, or even a quarter vault, on a square base, would stand if the walls were 10 lines thick, proving that the opposite parts, acting little more than against each other, the thrust becomes almost nothing.

1476. By the method of the centres of gravity, Rondelet found a result less than that above given; but that arose from neglecting some points in the calculation which it was difficult to introduce for general practice.

1477. It is obvious that in the above application great allowance must be made when the apartment to be vaulted is not square; that is, its advantages diminish as the two opposite sides become longer than the width, and when the length is twice the width, or even much less, the thrusts must be calculated on the principle of cylindrical vaulting; and as in this species of vaulting the greatest effort occurs in or towards the middle of the sides, opening for doors and windows should there be avoided.

Application of the Method to Spherical Vaulting.

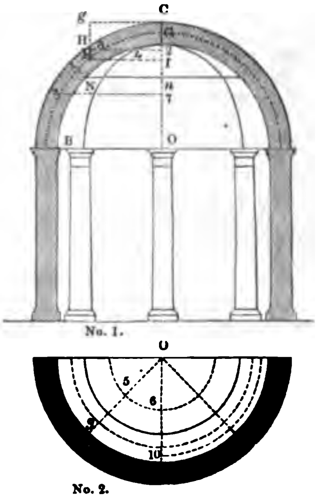
1478. The models (*fig.* 588. Nos. 1. and 2. and *fig.* 589. Nos. 1. and 2.) were of the same opening as the last mentioned. They are cut into eight equal parts by vertical planes crossing each other in the axis; each of these parts is subdivided by a joint at 45 degrees, altogether forming sixteen pieces. The vault stands on a circular wall of the same thickness divided into eight parts corresponding to those of the vault. All the parts are so arranged as to form continued joints without any bond, in order to give the experiment the most disadvantageous result. Yet it stood firmly, and was even capable of bearing a weight on the top.



No. 1

No. 2.

Fig. 588.



No. 1.

No. 2.

Fig. 589.

1479. If for these eight pieces of circular wall we substitute eight columns of equal height, as in No. 1. *fig.* 589., so that the vertical joints fall over the middle of each column; the vault will still stand, although the cube of these columns, as well as their weight, occupies only one ninth part of the circular wall for which they are substituted.

From this it is evident that spherical vaults have less thrusts than coved vaults.

1480. Applying the method of the preceding examples, describe the mean circumference (*fig.* 588. Nos. 1. and 2.), draw the tangents TF, GF, the secant FO, the horizontal line IKL, and the verticals KM and B*i*; lastly, calculating for one eighth of the vault, take the sector O*hm* to express the horizontal effort indicated by KL, and the part H*h*M*m* to express the horizontal effort of the lower part.

1481. The difference of these areas multiplied by the thickness of the vault will be the expression of the thrust *p* of the formula.

1482. The radius O*m* of the sector being $41\frac{5}{14}$ and its length $32\frac{1}{2}$, its area will be $672\frac{3}{56}$.

1483. The area of *h*HM*m* will be equal to the difference of the two sectors OHM and O*hm*, whereof the first is equal to the product of half OM = 27 by the arc HM = $42\frac{3}{7}$, or $1145\frac{4}{7}$, the second = $672\frac{3}{56}$; whence the difference = $473\frac{29}{56}$.

1484. The thrust, being equal to the difference between $672\frac{3}{56}$ and $473\frac{29}{56}$, will be $198\frac{30}{56} \times 9$; therefore $p = 786\frac{46}{56}$.

1485. f, representing the developement of one eighth part of the circular wall, will be $42\frac{1}{2}$, whence $\frac{p}{f}=42$. d, the difference between the arm of the lever and the height of the pier, being $41\frac{5}{12}$, we shall have $pd=73897\frac{1}{3}$.

1486. To obtain the value of mc we must first find that of m, which represents the vertical effort of the upper part of the vault, and is equal to the cube of this part multiplied by KM and divided by the arc KG. This cube is equal to the difference of the cube of the sector of a sphere in which it is comprised with that which forms its interior capacity. We will merely recall here to the reader's recollection from a previous page, that the cube of the sector of a sphere is equal to the product of the superficies of the sphere whereof it forms a part by one third of the radius, and that this superficies is equal to the product of the circumference of a great circle by the line which measures its depth. Thus the area of the great sector ORC*r* (*fig.* 588. No. 1.) is equal to the product of the great circle, whereof A*a* is the diameter $=126$, by $CS=18\frac{5}{11}$, which is 7308, and its cube $7308\times 21=153468$.

1487. The area of the small sector OND*n* will be equal to the product of the great circle, whereof B*b* is the diameter $=108$ by $VD=15\frac{9}{11}$, which gives $5369\frac{11}{77}$, and its cube by $5369\frac{11}{77}\times 18=96648\frac{44}{77}$. Deducting this last cube from that of the great sector already found $=153468$, the remainder 56819 will be the cube of the upper part of the vault forming the cap, whose eighth part $7102\frac{3}{8}$ will be the cube sought, which multiplied by $KM=17\frac{1}{4}$ and divided by the arc $KG=46$, gives $2646\frac{3}{8}$ for the value of m in the formula; c, which represents iK, being $12\frac{9}{14}$, we have

$$mc=33461\tfrac{1}{12};\ pd-mc \text{ will be } 73897\tfrac{1}{3}-33461\tfrac{1}{12}=40436\tfrac{1}{4};$$

$$\text{and for } \frac{pd-mc}{af},\ \frac{40436\frac{1}{4}}{120\times 42\frac{1}{2}}=7{\cdot}92.$$

1488. In the preceding application to the model of the coved vault, the walls being straight, the distance of their centre of gravity from the point of support was equal to half their thickness; in this, the wall being circular, its centre of gravity is so much more distant from the point of support as it takes in more or less a greater part of the circumference of the circle. By taking it only the eighth part, the centre of gravity falls without the thickness of the walls, by a quantity which we shall call e, so that the arm of the lever, instead of being $\frac{x}{2}$, will be $e+x$, which changes the preceding formula to

$$afx(e+x)+bx=pa+pd-mc;$$

arranging with reference to x, this becomes

$$afx^2+(eaf+b)x=pa+pd-mc;$$

whence we obtain $x^2+(e+\frac{b}{af})x=\frac{pa+pd-mc}{af}$, and making $e+\frac{af}{b}=2h$, we shall have

$$x=\sqrt{\frac{p}{f}+\frac{pd-mc}{af}+h^2}-h.$$

b expresses the vertical effort of an eighth part of the vault equal to its cube, multiplied by the vertical Bf, and divided by the mean circumference TKG. This cube is equal to an eighth of the sphere, whereof A*a* is the diameter, less that of the eighth part of a sphere whose diameter is B*b*.

1489. The diameter A*a* being 126, the eighth of the circumference of a great circle will be $49\frac{1}{2}$, which, multiplied by the vertical axis, which in this case is equal to the radius or 63, gives for the area of one eighth part of the sphere $3118\frac{1}{2}$, and for its cube $3118\frac{1}{2}\times 21=65688\frac{1}{2}$.

1490. The diameter B*b* being 108, an eighth part of the circumference of the great circle will be $42\frac{3}{7}$, which, multiplied by the radius 54, gives for the area $2291\frac{1}{7}$, and for its cube $2291\frac{1}{7}\times 18=41240\frac{4}{7}$; taking the smaller of these cubes from the greater, the difference $24447\frac{13}{14}$ will be that of this eighth part of the vault, which must be multiplied by $Bf=58\frac{1}{2}$, and the product $1430203\frac{23}{28}$, divided by the mean arc $TKG=91\frac{5}{7}$; the quotient 15558 expresses the vertical effort of the eighth part of the vault, represented by b in the formula, whence $\frac{b}{af}=\frac{15558}{5100}=3{\cdot}05$.

e being $2{\cdot}51$, we shall have for the value of h $2{\cdot}78$ and $h^2=7{\cdot}72$.

Substituting the values thus found in the formula

$$x=\sqrt{\frac{p}{f}+\frac{pd-mc}{af}+hh}-h,$$

$$\text{we have } x=\sqrt{42+7{\cdot}92+7{\cdot}72}-2{\cdot}78=\sqrt{57{\cdot}64}-2{\cdot}78=4{\cdot}72.$$

By using the method of the centres of gravity, Rondelet found the result rather less than that just found.

1491. The result of all these calculations induces the following facts: — I. That for a semicircular cylindrical vault, whose length is equal to its diameter, the area of the two parallel walls is 4698. II. That that of the four square piers supporting a groined arch is 7056. III. That of the four walls of the coved vault, the area should be 3425⅝. IV. That that of the spherical vault is 1238¼.

1492. In respect of the opening of these vaults, which is the same for all the examples, taking the area of the circular wall for the spherical vault at 1,

That of the walls of the coved vault will be a little less than 3.
That of the cylindrical vault - - less than 4.
That of the groined arch - - less than 6.

But if we look to the space that each of these vaults occupies in respect of walls and points of support, we shall find that in equal areas the walls of the cylindrical vault will be ²⁄₇ of such space.

Those of the coved vaulting less than - - ¼ of such space.
The piers of the groined arch a little more than - ⅐ —
The circular wall for spherical vault a little more than ²⁄₁₇ —

So that, if we suppose the space occupied by each of these vaults to be 400,

The walls of the cylindrical vaulting will be 115
Those for the coved vault - - 91
The piers for the groined arch - 60
The circular wall for the spherical vault - 48

Which figures therefore show the relative proportions of the points of support necessary in each case.

1493. It is a remarkable circumstance that by the formula the coved and spherical vaults give to the walls a less thickness than that of the arch. But although experiment has verified the formula, we cannot be supposed to recommend that they should be made of less thickness in practice; but we see that, if of the same thickness, considerable openings may be used in them. Irregular as well as regular compound vaults being only an assemblage of the parts of more simple ones, if what has already been said be well understood, and the examples given have been worked out by the student, he will not be much at a loss in determining the efforts of all sorts of vaults.

On the adhesive Power of Mortar and Plaster upon Stones and Bricks.

1494. The power of mortar and plaster will of course be in proportion to the surface of the joints, compared with the masses of stone, brick, or rubble. Thus a voussoir of wrought stone, one foot cube, may be connected with the adjoining voussoirs by four joints, each of 1 foot area, in all 4 feet. But if instead of this voussoir three pieces of rough stone or rubble be substituted instead of 4 feet area of joints, we shall have 8. Lastly, if bricks be employed instead of rubble, we shall want 27 to form the same mass, which gives for the developement of the joints 13 feet. Thus, representing the force which connects the voussoirs in wrought stone by 4, that representing the joints of the rough stones will be 8, and that for bricks 13: whence we may infer that arches built with rough stones will have less thrust than those in wrought stone, and those in bricks more than three times less. From experiments made by Rondelet, he found that at the end of six months some species of mortar showed a capability of uniting bricks with sufficient force to overcome the efforts of thrust in a vault segmental to ⅔ of a semicircle, 15 feet diameter and 4 inches thick, the extrados being 4 inches concentrically above the intrados. Plaster united a vaulted arch of 18 feet opening, of the same form and thickness. This force is, moreover, greater in arches whose voussoirs increase from the keystone to the springing, and that in proportion to the thickness at the haunches, where fracture takes place; so that whatever the diameter and form of the arch, the strength of good mortar at the end of six months, if the arches are well constructed, is capable of suppressing the thrust as long as the thickness, taken at the middle of the haunches, is stronger than the tenth part of those laid in mortar, and one twelfth of those laid in plaster. Here we have to observe, that arches laid in plaster, as long as they are kept dry and sheltered from the changes of the season, preserve their strength, but, on the contrary, they lose all their stability in seven or eight years, whilst those cemented in mortar endure for ages.

1495. The small quantity of mortar or of plaster used in vaults constructed of wrought stone, in which the joints are often little more than *rus*, ought to make an architect cautious of depending merely on the cementing medium for uniting the voussoirs. There are other means which he may employ in cases of doubt, such as *dowels* and *cramps*, means which were much employed by the Romans in their construction; and these are far better than the chains and ties of iron introduced by the moderns.

1496. The thrust of an arch is, in practice, the constant dread of an architect; but it depends entirely on the method employed in the construction. It is only dangerous where the precautions indicated in the foregoing examples are altogether lost sight of. It has been seen that the least fracture in too thin an arch of equally deep voussoirs may cause its ruin; and we shall here add, that this defect is more dangerous in arches wherein the number of joints is many, such as those constructed in brick; for when they are laid in mortar they are rather heaped together than well fitted to each other.

1497. Whatever materials are used in the construction of vaults, the great object is to prevent separation, which, if it occur, must be immediately met by measures for making the resistance of the lower parts capable of counterbalancing the effort of the upper parts. Those fractures which occur in cylindrical arches are the most dangerous, because they take place in straight lines which run along parallel to the walls bearing them. To avoid the consequences of such failures, it is well to fill up the haunches to the height where the fracture is usually to be found, as in K, K′, K″, K‴ (*fig.* 590.) and diminish the thickness towards the key.

1498. Rondelet found, and so indeed did Couplet before him, that the least thickness which an arch of equal voussoirs ought to have, to be capable of standing, was one fiftieth part of the radius. But as the bricks and stone employed in the construction of arches are never so perfectly formed as the theory supposes, the least thickness which can be used for cylindrical arches from 9 to 15 feet radius is $4\frac{1}{2}$ inches at the vertex if the lower course be laid with a course of brick on edge or two courses flatwise, and 5 inches when the material used is not a very hard stone, increasing the thickness from the keystone to the point where the extrados leaves the walls or piers. But if the haunches are filled up to the point N (*fig.* 590.), it will be found that for the pointed arch in the figure the thickness need not be more than the $\frac{1}{143}$ of the radius, and for the semicircular arch, $\frac{1}{80}$. For arches whose height is less than their opening or that are segmental the thickness should be $\frac{1}{3}$ part of the versed sine; a practice also applicable to Gothic vaults and semicircular cylindrical arches, to which for vaults cemented with plaster one line should be added for each foot in length, or $\frac{1}{144}$ part of the chord subtended by the extrados. With vaults executed in mortar $\frac{1}{96}$ may be added, the thickness of the arch increasing till it reaches the point N, where the arch becomes detached from the haunches, and where it should be once and a half the thickness of the key. It was in this way the arches throughout the Pantheon at Paris were regulated, and a very similar sort of expedient is practised in the dome of the Pantheon at Rome. A like diminution at the keystone may be used in groined, coved, and spherical vaults.

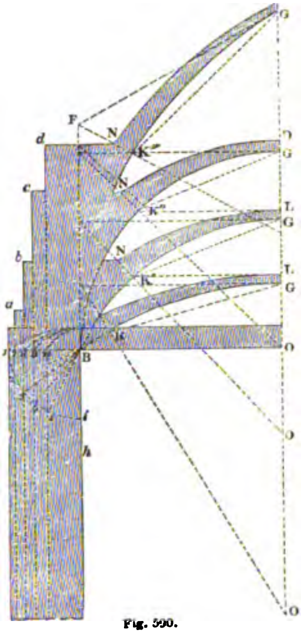


Fig. 590.

1499. For vaultings of large openings, Rondelet (and we fully concur with him) thinks wrought stone preferable to brick or rubble stone. They have the advantage of being liable to less settlement and to stand more independent of any cementitious medium employed. It is indeed true that this cannot connect wrought stone so powerfully as it does rubble; but in the former we can employ cramps and dowells at the joints, which are useful in doubtful cases to prevent derangement of the parts. In many Roman ruins the surfaces of the voussoirs were embossed and hollowed at the joints, for the purpose of preventing their sliding upon each other; and expedients of the same nature are frequently found in Gothic ruins.

Sect. X.

WALLS.

1500. The thickness which is to be assigned to walls and points of support, that their stability may be insured, depends on the weight they have to sustain, and on their formation with proper materials; still more on the proportion which their bases bear to their heights. The crushing of stone and brick, by mere superimposed weight, is of such extremely rare occurrence in practice, even with soft stone and with bad bricks, that we think it sufficient to give the result of the some few experiments that have been made in that respect, to give the reader some notion of the resistance of our bricks and stones to a crushing force. This is exhibited in the subjoined table: —

Materials.	Specific Gravity.	Crushing Weight.
		lbs.
Portland stone, 2 inches long 1 inch high	- -	805
Statuary marble, 1 inch cube of	- -	3216
Cragleith stone, ditto	- -	8688
Chalk, cube of 1½ inch	- -	1127
Pale red brick, ditto	2085	1265
Roe stone, Gloucestershire, ditto	- -	1449
Red brick, ditto	2168	1817
Hammersmith brick, called pavior's ditto	- -	2254
Ditto burnt, ditto	- -	3242
Ditto fire-brick, ditto	- -	3864
Derby grit, ditto	2316	7070
Another specimen, ditto	2428	9776
Killala white freestone, ditto	2423	10,264
Portland, ditto	2428	10,284
Cragleith white freestone, ditto	2452	12,346
Yorkshire paving, with the strata, ditto	2507	12,856
Ditto, ditto, against strata, ditto	- -	12,856
White statuary marble, ditto	2760	13,632
Bramley Fall sandstone, ditto	2506	13,632
Ditto, against strata, ditto	- -	13,632
Cornish granite, ditto	2662	14,302
Dundee sandstone, ditto	2530	14,918
Portland, a 2 inch cube	2423	14,918
Cragleith, with the strata, 1½ inch cube	2452	15,360
Devonshire red marble	- -	16,732
Compact limestone	2584	17,354
Peterhead granite	- -	18,636
Black compact limestone	2598	19,924
Purbeck	2599	20,610
Freestone, very hard	2528	21,254
Black Brabant marble	2697	20,742
White Italian marble	2726	21,783
Aberdeen granite, blue kind	2625	24,556

1501. The above experiments lose much of their practical value from our knowledge that the interior particles in granulated substances are protected from yielding by the lateral resistance of the exterior ones; but to what extent it is impossible to estimate, because so much depends on the internal structure of the body. We are, however, thus far informed, that, taking into account the weight with which a point of support is loaded, its thickness ought to be regulated in an inverse ratio to the crushing weight of the material employed. In Gothic structures we often see, for instance, in chapter houses with a central column, a prodigious weight superimposed. It is needless to say, that, in such instances, the strongest material was necessary, and we always find it so employed. So, in the columns, or rather pillars, of the naves in such edifices, the greatest care was taken to select the hardest stone.

1502. Generally speaking, the thickness of walls and piers should be proportioned rather to their height than to the weight they are to bear; hence often the employment of a better material, though more costly, is in truth the most economical.

Of the Stability of Walls.

1503. In the construction of edifices there are three degrees of stability assignable to walls. I. One of undoubted stability; II. A mean between the last; and the III. The least thickness which they ought to possess.

1504. The first case is that in which from many examples we find the thickness equal to one eighth part of the height: a mean stability is obtained when the thickness is one tenth part of the height; and the minimum of stability when one twelfth of its height. We are, however, to recollect that in most buildings one wall becomes connected with another, so that stability may be obtained by considering them otherwise than as independent walls.

1505. That some idea may be formed of the difference between a wall entirely isolated and one connected with one or two others at right angles, we here give *figs.* 591, 592, and 593. It is obvious that in the first case (*fig.* 591.), a wall acted upon by the horizontal force MN, will have no resistance but from the breadth of its base; that in the second

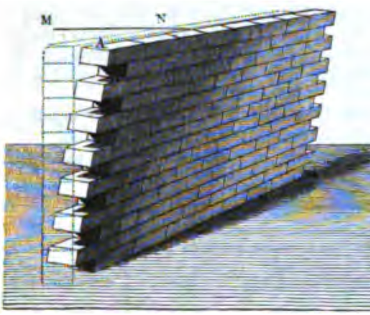


Fig. 591.

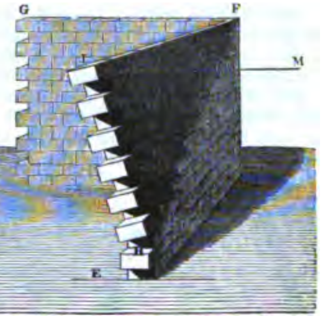


Fig. 592.

case (*fig.* 592.) the wall GF is opposed to the force MN, so that only the triangle of it HIF can be detached; lastly, in *fig.* 593. the force MN would only be effective against

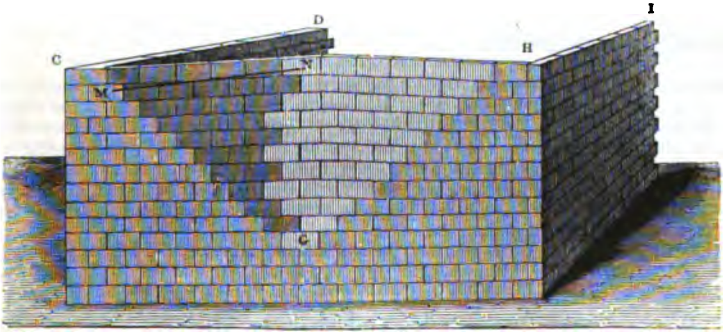


Fig. 593.

the triangle CGH, which would, of course, be greater in proportion to the increased distance of the walls CD, HI.

1506. In the first case, the unequal settlement of the soil or of the construction may produce the effect of the force MN. The wall will fall on the occurrence of an horizontal disunion between the parts.

1507. In the second case the disunion must take place obliquely, which will require a greater effort of the power MN.

1508. In the third case, in order to overturn the wall, there must be three fractures through the effort of MN, requiring a much more considerable force than in the second case.

1509. We may easily conceive that the resistance of a wall standing between two others will be greater or less as the walls CD, HI are more or less distant; so that, in an extreme approximation to one another, the fracture would be impossible, and, in the opposite case, the intermediate wall approaches the case of an isolated wall.

1510. Walls enclosing a space are in the preceding predicament, because they mutually tend to sustain one another at their extremities; hence their thickness should increase as their length increases.

1511. The result of a vast number of experiments by Rondelet, whose work we are still using, will be detailed in the following observations and calculations.

1512. Let ABCD (*fig.* 594.) be the face of one of the walls for enclosing a rectangular

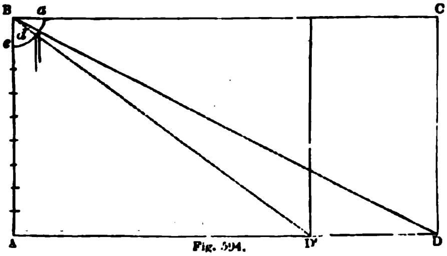


Fig. 594.

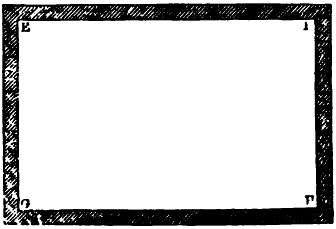


Fig. 595.

space, EFGH (*fig.* 595.). Draw the diagonal BD, and above B make B*d* equal to one eighth part of the height, if great stability be required; for a mean stability, the ninth or tenth part; and, for a light stability, the eleventh or twelfth part. If through the point *d* a parallel to AB be drawn, the interval will give the thickness to be assigned to the great walls EF, GH, whose length is equal to AD.

1513. The thickness of the walls EG, FH is obtained by making AD′ equal to their length, and, having drawn the diagonal as before, pursuing the same operation.

1514. When the walls are of the same height but of different lengths, as in *fig.* 596., the operation may be abridged by describing on the point B (*fig.* 597.) as a centre with a radius equal to one eighth, one tenth, or one twelfth, or such other part of the height as may be considered necessary for a solid, mean, or lighter construction, then transferring their lengths, EF, FG, GH, and HE from A to D, D′, D″, and D‴; and having made the rectangles AC, AC′, AC″, and AC‴, draw from the common point B the diagonals BD, BD′, BD″, and BD‴, cutting the small circle described on the point B in different points, through which parallels to AB are to be drawn, and they will give the thickness of each in proportion to its length.

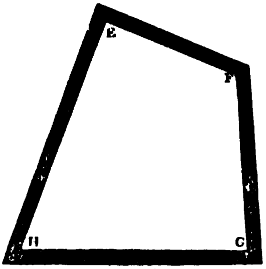


Fig. 596.

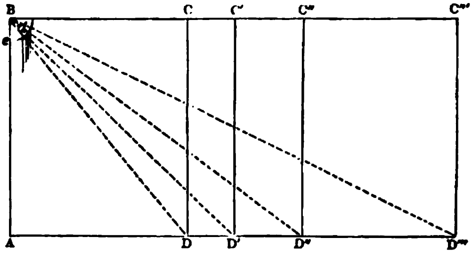


Fig 597.

1515. In *figs.* 598. to 602. are given the operations for finding the thicknesses of walls enclosing polygonal areas supposed to be of the same height; thus AD represents the side of the hexagon (*fig.* 602.); AD′ that of the pentagon (*fig.* 601.); AD″ the side of the square (*fig.* 599.); and AD‴ that of the equilateral triangle (*fig.* 600.).

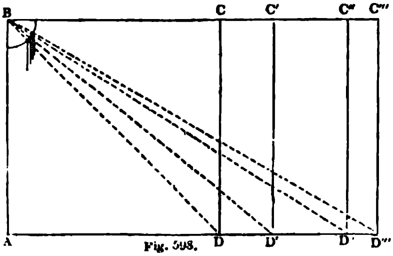


Fig. 598.

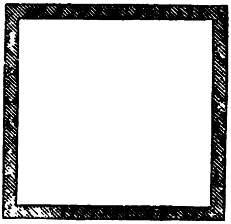


Fig. 599.

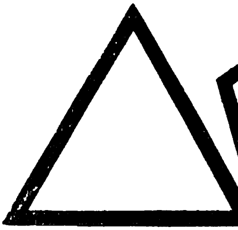


Fig. 600.

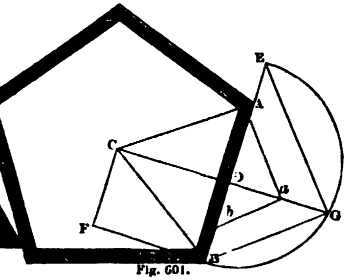


Fig. 601.

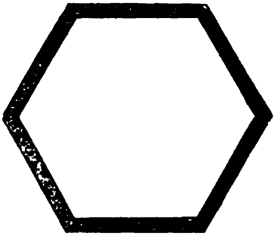


Fig. 602.

1516. It is manifest that, by this method, we increase the thicknesses of the walls in proportion to their heights and lengths; for one or the other, or both, cannot increase or diminish without the same happening to the diagonal.

1517. It is obvious that it is easy to calculate in numbers the results thus geometrically obtained by the simple rule of three; for, knowing the three sides of the triangle ABD, similar to the smaller triangle *Bde*, we have BD : B*d*::AD : *ed*. Thus, suppose the length of wall represented by AD = 28 feet, and its height AB = 12 feet, we shall have the length of the diagonal = 30 feet $5\frac{1}{2}$ inches; and, taking the ninth part of AB, or 16 inches, as the thickness to be transferred on the diagonal from B to *d*, we have 30 ft. 6 in. : 16 in.::28 ft. : 14 in. : 8 lines (*ed*). The calculation may also be made trigonometrically; into which there is no necessity to enter, inasmuch as the rules for obtaining the result may be referred to in the section "Trigonometry," and from thence here applied.

Method of enclosing a given Area in any regular Polygon.

1518. It is manifest that a polygon may be divided by lines from the centre to its angles into as many triangles as it has sides. In *fig.* 601., on one of these triangles let fall from c (which is the vertex of each triangle a perpendicular CD) a vertical on the base or side AB which is supposed horizontal. The area of this triangle is equal to the product of DB (half AB) by CD, or to the rectangle DCFB. Making $DB = x$, $CD = y$, and the area given $= p$, we shall have,

For the equilateral triangle, $x \times y \times 3 = p$, or $xy = \frac{p}{3}$;
For the square, $xy \times 4 = p$, or $xy = \frac{p}{4}$;
For the pentagon, $xy \times 5 = p$, or $xy = \frac{p}{5}$;
For the hexagon, $xy \times 6 = p$, or $xy = \frac{p}{6}$.

Each of these equations containing two unknown quantities, it becomes necessary to ascertain the proportion of x to y, which is as the sines of the angles opposite to the sides DB and CD.

1519. In the equilateral triangle this proportion is as the sine of 60 degrees to the sine of 30 degrees; that is, using a table of sines, as 86603 : 50000, or $8\frac{2}{3}$: 5, or 26 : 15, whence

$$x : y :: 26 : 15, \text{ and } 15x = 26y; \text{ whence } y = \frac{15x}{26}.$$

Substituting this value in the equation $xy = \frac{p}{3}$, we have

$$\frac{15xx}{26} = \frac{p}{3}, \text{ which becomes } xx = \frac{26p}{45}, \text{ and } x = \sqrt{\frac{26p}{45}}.$$

Supposing the area given to be 3600, we shall therefore have

$$x = \sqrt{\frac{3600 \times 26}{45}} = 45{\cdot}6, \text{ and the side } AB = 91{\cdot}2.$$

For the pentagon, $x : y ::$ sin. 36° : sin. 54°, or as 58779 : 80902, whence

$$y = \frac{80902x}{58799}.$$

Substituting this value in the equation $xy = \frac{p}{5}$, we have

$$\frac{80902xx}{58779} = \frac{3600}{5}, \text{ and } x = \sqrt{\frac{58779 \times 720}{80902}};$$

which makes $x = 22{\cdot}87$, and this side $AB = 45{\cdot}74$.

For the hexagon, $x : y ::$ sin. 30° : sin. 60°, or as 50000 : 86603::5 : $8\frac{2}{3}$, whence the value of $y = \frac{26x}{15}$. This value, substituted in the equation $xy = \frac{p}{6}$, will give $\frac{26xx}{15} = 600$; whence $xx = \frac{600 \times 15}{26}$; lastly, therefore, $x = \sqrt{346{\cdot}15} = 18{\cdot}61$, and the side $AB = 37{\cdot}22$.

Geometrically.

1520. Suppose the case that of a pentagon (*fig.* 601.) one of whose equal triangles is ACB. Let fall the perpendicular CD, which divides it into two equal parts; whence its area is equal to the rectangle CDBF.

1521. Upon the side AB, prolonged, if necessary, make DE equal to CD, and from the middle of BE as a centre describe the semi-circumference cutting CD in G, and GD will be the side of a square of the same area as the rectangle CDBF. The sides of similar figures (Geometry, 961.) being as the square roots of their areas; find the square root of the given area and make D*g* equal to it. From the point *g* draw parallels to GE and GB, which will determine on AB the points *e* and *b*, which will give on one side D*b* equal to one half of the side of the polygon sought; and, on the other, the radius D*e* of the circumference in which it is inscribed. This is manifest because of the similar triangles EGB and *egb*, from which BD : DE::*b*D : D*e*.

1522. From the truth that the sides of similar figures are to each other as the square roots of their areas we arrive at a simple method of reducing any figure to a given area. Form an angle of reduction (*fig.* 603.) one of whose sides is equal to the square root of the greater area, and the chord of the arc, which determines the size of the angle equal to the square root of the smaller area. Let, for instance, the larger area =1156, and that of the smaller, to which the figure is to be reduced, =529. Draw an indefinite line, on which make AB=34, the square root of 1156. Lastly, from the point A, as a centre, having described an indefinite arc, with a length equal to the square root 23 of 529, set out B*g*; through *g* draw A*g*, which will be the angle of reduction *g*AB, by means of which the figure may be reduced, transferring all the measures of the larger area to the line AD, with which arcs are to be described whose chords will be the sides sought.

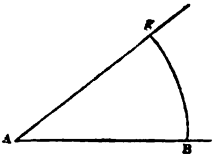


Fig. 593.

1523. If it be not required to reduce but to describe a figure whose area and form are given, we must make a large diagram of any area larger than that sought, and then reduce it.

1524. The circle, as we have already observed in a previous subsection (933.), being but a polygon of an infinite number of sides, it would follow that a circular enclosure would be stable with an infinitely small thickness of wall. This property may be easily demonstrated by a very simple experiment. Take, for instance, a sheet of paper, which would not easily be made to stand while extended to its full length, but the moment it is bent into the form of a cylinder it acquires a stability, though its thickness be not a thousandth part of its height.

1525. But as walls must have a certain thickness to acquire stability, inasmuch as they are composed of particles susceptible of separation, we may consider a circular enclosure as a regular polygon of twelve sides, and determine its thickness by the preceding process. Or, to render the operation more simple, find the thickness of a straight wall whose length is equal to one half the radius.

1526. Suppose, for example, a circular space of 56 ft. diameter and 18 ft. high, and the thickness of the wall be required. Describe the rectangle ABCD (*fig.* 594.), whose base is equal to half the radius, that is, 14 ft., and whose height AB is 18 ft.; then, drawing the diagonal BD, make B*d* equal to the ninth part of the height, that is, 2 ft. Through *d* draw *ad* parallel to the base, and its length will represent the thickness sought, which is 14¾ inches.

1527. By calculation. Add the square of the height to that of half the radius, that is, of 18=324, and of 14·196=520. Then extract the square root of 520, which will be found =22·8, and this will be the value of the diagonal BD. Then we have the following proportion: 22·8 : 14 :: 2 ft. (⅑ the height) : 14·74.

1528. The exterior wall of the church of *St. Stefano Rotondo* at Rome (Temple of Claudius) incloses a site 198 feet diameter. The wall, which is contructed of rubble masonry faced with bricks, is 2 ft. 4 in. (French) thick, and 22½ ft. high. In applying to it the preceding rule, we shall find the diagonal of the rectangle, whose base would be the side of a polygon, equal to half the radius and 22½ ft. high, would be $\sqrt{49\frac{1}{2}\times 49\frac{1}{2}+22\frac{1}{2}\times 22\frac{1}{2}}=54\frac{37}{100}$. Then, using the proportion 54·37 : 49·5 :: $\frac{22\frac{1}{2}}{9}$: 2 ft. 3 in. and 4 lines, the thickness sought, instead of 2 ft. 4 in., the actual thickness. We may as well mention in this place that a circle encloses the greatest quantity of area with the least quantity of walling; and of polygons, those with a greater number of sides more than those with a lesser: the proportion of the wall in the circle being 31416 to an area of 78540000; whilst in a square, for the same area, a length of wall equal to 35448 would be required. As the square falls away to a flat parallelogram, say one whose sides are half as great, and the others double the length of those of the square, or 17724 by 4431, in which the area will be about 78540000, as before; we have in such a case a length of walling =44310.

On the Thickness of Walls in Buildings not vaulted.

1529. The walls of a building are usually connected and stiffened by the timbers of the roof, supposing that to be well constructed. Some of the larger edifices, such as the ancient basilicæ at Rome, have no other covering but the roof; others have only a simple ceiling under the roof; whereas, in palaces and other habitations, there are sometimes two or more floors introduced in the roof.

1530. We will begin with those edifices covered with merely a roof of carpentry, which are, after mere walls of enclosure, the most simple.

1531. Among edifices of this species, there are some with continued points of support, such as those wherein the walls are connected and mutually support each other; others in which the points of support are not connected with each other, such as piers, columns, and pilasters, united only by arcades which spring from them.

1532. When the carpentry forming the roof of an edifice is of great extent, instead of being injurious to the stability of the walls or points of support, it is useful in keeping them together.

1533. Many edifices exist wherein the walls and points of support would not stand without the aid of the carpentry of the roofs that cover them.

1534. The old basilica of *St. Paolo fuorì le murà* at Rome was divided into five naves formed by four ranks of columns connected by arcades, which carried the walls whereon the roof rested; the centre nave 73½ ft. (French) wide, and 93 ft. 10 in. high. The walls of it are erected on columns 31 ft. 9 in. high, and their thickness is a little less than 3 ft., that is, only $\frac{1}{32}$ part of their height.

1535. At Hadrian's Villa the most lofty walls, still standing, were but sixteen times their thickness in height, and 51 ft. 9 in. long. The walls were the enclosures of large halls with only a single story, but assisted at their ends by cross walls. And we may therefore conclude that if the walls of the basilica above mentioned were not kept in their places by the carpentry of the great roof they would not be safe. It is curious that this supposition, under the theory, was proved by the fire which destroyed the church of St. Paolo in 1823. The walls which form the nave of the church of Santa Sabina are raised on columns altogether 52 ft. high; they are 145 ft. long, and somewhat less than 2 ft., that is, $\frac{1}{26}$ part of their height, in thickness. They are, therefore, not in a condition of stability without the aid of the roof. In comparing, however, the thickness of these walls with the height only of the side aisles, in the basilica of St. Paolo the thickness is $\frac{1}{17}$, and at Santa Sabina $\frac{1}{13}$. In the other basilicæ or churches with columns, the least thickness of wall is $\frac{1}{13}$ of greater proportion unconnected with the nave, as at Santa Maria Maggiore, Santa Maria in Trastevere, St. Chrysogono, St. Pietro in Vincolà, in Rome; St. Lorenzo and St. Spirito, in Florence; St. Filippo Neri, at Naples; St. Giuseppe and St. Dominico, at Palermo.

1536. We must take into account, moreover, that the thickness of walls depends as much on the manner in which they are constructed, as on their height and the weight with which they are loaded. A wall of rough or squared stone 12 inches thick, wherein all the stones run right through the walls in one piece, is sometimes stronger than one of 18 or 20 inches in thickness, in which the depth of the stones is not more than half or a third of the thickness, and the inner part filled in with rubble in a bad careless way. We are also to recollect that stability more than strength is ofttimes the safeguard of a building; for it is certain that a wall of hard stone 4 inches thick would be stronger than would be necessary to bear a load equal to four or five stories, where a thickness of 18 inches is used; and yet it is manifest that such a wall would be very unstable, because of the narrowness of the base.

1537. From an examination which Rondelet made of 280 buildings in France and Italy, ancient as well as modern, he found that in those covered with roofs of two inclined sides and constructed in framed carpentry, with and without ceilings, and so trussed as not to act at all horizontally upon the walls, the least thickness in brick or rough stones was $\frac{1}{24}$ of the width in the clear.

1538. In private houses, divided into several stories by floors, it was observed, generally, that the exterior walls ran from 15 to 24 inches, party walls 16 to 20 inches, and partition walls 12 to 18 inches.

1539. In buildings on a larger scale, exterior walls 2 to 3 feet thick, party walls 20 to 24 inches, partition walls 15 to 20 inches.

1540. In palaces and buildings of great importance, whose ground floors are vaulted, the exterior walls varied from 4 to 9 feet, and the partition walls from 2 to 6 feet. In many of the examples which underwent examination, the thicknesses of the walls and points of support were not always well proportioned to their position, to the space they enclosed, nor to the loads they bore. In some, great voids occur, and considerable loads were supplied with but slender walls and points of support; and in others, very thick walls enclosed very small spaces, and strong points of support had but little to carry.

1541. For the purpose of establishing some method which in a sure and simple manner would determine the thickness of walls in buildings which are not arched, we have considered, says Rondelet, that the tie-beams of the trusses of carpentry whereof the roofs are composed, being always placed in the direction of the width, as well as the girders and leading timbers of floors, serve rather to steady and connect the opposite walls; but, considering the elasticity and flexibility of timber, it is found that they strain the walls which support them in proportion to the widths of the spaces enclosed, whence it becomes often the better plan to determine the thickness of the walls from the width and height of the apartments requisite. Hence the following rules.

First Rule.

1542. In buildings covered with a simple roof, if the walls are insulated throughout, their height up to the under side of the tie-beams of the trusses, being as shown in *fig.* 604. Having drawn the diagonal BD and thereon made B*b* and D*d*, equal to the twelfth part of the height AB, then through the points *b* and *d*, draw lines parallel to BA and DC, which will bound the thickness of the walls required.

1543. If the height AB and width AD be known, the thickness A*c* may be calculated, seeing that $BD=\sqrt{AB^2+AD^2}$; knowing the value of BD, we have that of *c*A by the proportion AD : AD :: B : $cA=\frac{AD\times Bb}{BD}$.

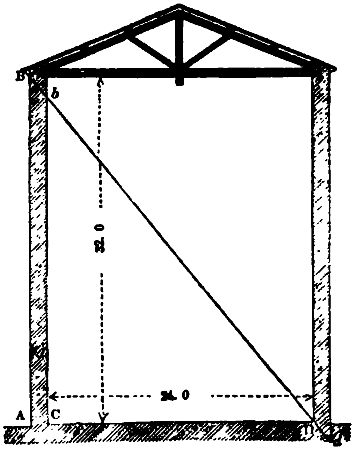


Fig. 604.

First Example.

1544. Supposing the width BC = 24 ft., and the height AB = 32, we shall have

$\sqrt{AB^2+AD^2}=\sqrt{24\times24+32\times32}$; whence $BD=\sqrt{576+1024}=\sqrt{1600}=40$ ft.

B*b*, which is the twelfth part of AD, or of 32 ft. = 2 ft. 8 in.; the thickness of the wall expressed by $\frac{AD\times Bb}{BD}$, will be $\frac{24\times2\frac{2}{3}}{40}=1\frac{3}{5}$ ft., or 1 ft. 7 in. 2 lines, for the thickness sought.

1545. If the walls supporting the roof were stiffened by extra means, such as lower roofs at an intermediate height, as in churches with a nave and side aisles, we may make B*e* in the diagonal BD equal to one twelfth of the height above the springing of the side roofs, and *ef* a twenty-fourth part of that height below it, and draw through the point *f* a line parallel to AB, which will determine the thickness A*f* sought; or, which amounts to the same thing, add together the total height AB of the interior, and that of EB above the point of support, E, whereof take the twenty-fourth part, which will be equal to B*e* + *ef*.

Second Example.

1546. *Fig.* 605. is a section of St. Paolo fuori le murà, near Rome, as it was in 1816.

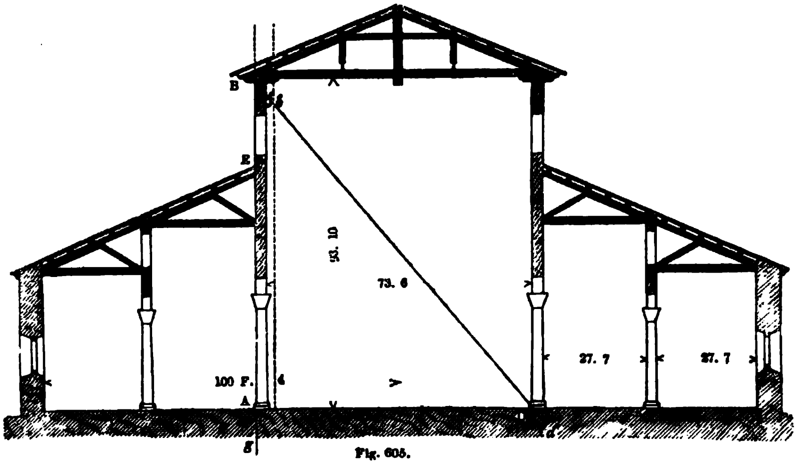


Fig. 605.

The interior height to the under side of the tie-beams is 93 ft. 10 in. (French), whereof 26 ft. 2 in. is the exterior height above the roofs of the side aisles. These two dimensions together make 120 ft., whose twenty-fourth part is 5 ft., to which, on the diagonal BD, make B*f* equal; then from the point *f* letting fall a vertical line, the horizontal line B*e* will determine the thickness, which will be 3 ft., the width of the nave being 73 ft. 6 in. In figures, as follows: —

$$BD=\sqrt{93\text{ ft. }10\text{ in.}\times93\text{ ft. }10\text{ in.}+73\text{ ft. }6\text{ in.}\times73\text{ ft. }6\text{ in.}}=\sqrt{14207}=119\text{ ft. }2\text{ in.}$$

1547. For the thickness, *e*B, as before, BD : AD :: B*f* : A*f*′; whence, $Af'=\frac{AD\times Bf}{BD}=\frac{73\frac{1}{2}\times5}{119\text{ ft. }2\text{ in.}}=3$ ft. 1 in.; instead of 2 ft. 11 in. 9 lines, the actual thickness of the walls.

1548. The same calculation being applied to the walls of the nave of Santa Sabina

(Rome), whose height of nave is 51 ft. 2 in, and width 42 ft. 2 in., with a height of 16 ft. of wall above the side aisles, gives 21 in. 4 lines, and they are actually a little less than 24 in.

1549. In the church of Santa Maria Maggiore, the width is 52 ft. 7½ in., and 56 ft. 6 in. and 4 lines high, to the ceiling under the roof. The height of the wall above the side aisles is 19 ft. 8 in., and the calculation requires the thickness of the walls to be 26¼ in. instead of 28¾ in., their actual thickness.

1550. In the church of St. Lorenzo, at Florence, the internal width of the nave is 37 ft. 9 in., and the height 69 ft. to the wooden ceiling; from the side aisles the wall is 18 ft. high. The result of the calculation is 21 in., and the actual execution 21 in. and 6 lines.

1551. The church of Santo Spirito, in the same city, which has a wooden ceiling suspended to the trusses of the roof, is 76 ft. high and 37 ft. 4 in. wide in the nave the walls rise 19 ft. above the side aisles. From an application of the rule the thickness should be 21 in. 3 lines, and their thickness is 22½ in.

1552. In the church of St. Philippo Neri, at Naples, the calculation requires a thickness of 21 in., their actual thickness being 22½ in.

1553. In the churches here cited, the external walls are much thicker; which was necessary, from the lower roofs being applied as *leantoes*, and hence having a tendency, in case of defective framing of them, to thrust out the external walls. Thus, in the church of St. Paolo, the walls are 7 ft. thick, their height 40 ft.; 3 ft. 4 in. only being the thickness required by the rule. A resistance is thus given capable of assisting the walls of the aisles, which are raised on isolated columns, and one which they require.

1554. In the church of Santa Sabina, the exterior wall, which is 26 ft. high, is, as the rule indicates, 26 in. thick; but the nave is flanked with a single aisle only on each side, and the walls of the nave are thicker in proportion to the height, and are not so high. For at St. Paolo the thickness of the walls is only $\frac{1}{24}$ of the interior width, whilst at Santa Sabina it is $\frac{1}{17}$. At San Lorenzo and San Spirito the introduction of the side chapels affords great assistance to the external walls.

Examples for the Thickness of Walls of Houses of many Stories.

1555. As in the preceding case, the rules which Rondelet gives are the result of observations on a vast number of buildings that have been executed, so that the method proposed is founded on practice as well as on theory.

1556. In ordinary houses, wherein the height of the floors rarely exceeds 12 to 15 ft., in order to apportion the proper thickness to the interior or partition walls, we must be guided by the widths of the spaces they separate, and the number of floors they have to carry. With respect to the external walls, their thickness will depend on the depth and height of the building. Thus a *single* house, as the phrase is, that is, only one set of apartments in depth, requires thicker external walls than a *double* house, that is, more than one apartment in depth, of the same sort and height; because the stability is in the inverse ratio of the width.

1557. Let us take the first of the two cases (*fig.* 606.), whose depth is 24 ft. and height to the under side of the roof 36 ft. Add to 24 ft. the half of the height, 18, and take $\frac{1}{24}$ part of the sum 42, that is, 21 in., for the least thickness of each of the external walls above the *set-off* on the ground floor. For a mean stability add an inch, and for one still more solid add two inches.

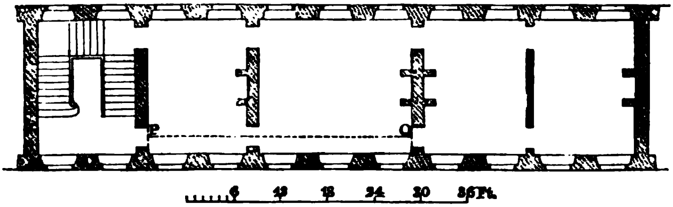


Fig. 606.

1558. In the case of a double house (*fig.* 607.) with a depth of 42 ft., and of the same height as the preceding example, add half the height to the width of the building; that is, 21 to 18, and $\frac{1}{24}$ of the sum $= 19\frac{1}{2}$ is the thickness of the walls. To determine the thickness of the partition walls, add to their distance from each other the height of the story, and take $\frac{1}{36}$ of the sum. Thus, to find the thickness of the wall IK, which divides the space LM into two parts and is 32 ft., add the height of the story, which we will take at 10 ft., making in all 42 ft., and take $\frac{1}{36}$ or 14 in. Half an inch may be added for each story above the ground floor. Thus, where three stories occur above the ground floor, the thickness in

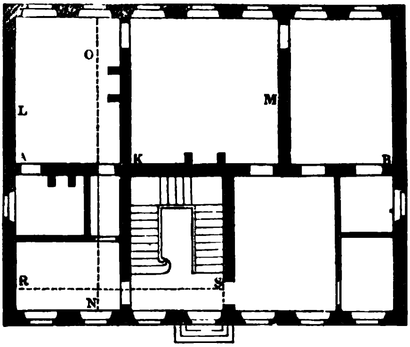


Fig. 607.

the lower one would be 15½ in., a thickness which is well calculated for bricks and stone, whose hardness is of a mean description.

1559. For the wall AB, which divides the space between the external walls, equal to 35 ft., add to it the height, which is 10 ft., and $\frac{1}{36}$ of 45, the sum of the two; that is, 15 in. is the thickness required for the wall, if only to be carried up a single story; but if through more, then add half an inch, as before, for each story above the ground floor. For the spaces NO, PQ, RS, in this and the preceding figure, the repetition of the operation will give their thicknesses.

1560. To illustrate what has been said, *fig.* 608. is introduced to the reader, being the plan of a house in the Rue d' Enfer, near the Luxembourg, known as the Hotel Vendôme, built by Le Blond. It is given by Daviller in his *Cours d'Architecture*. The building is 46 ft. deep on the right side and 47 ft. in the middle, and is 33 ft. high from the pavement to the entablature. Hence, to obtain the thickness of the walls on the line FF, take the sum of the height and width $=\frac{47+33}{2}=40$ ft., whose twenty-fourth part is 20 in. The building being one of solidity, let 2 in. be added, and we obtain 22 in. instead of 2 ft., which is their actual thickness. For the thickness of the interior wall, which crosses the building in the direction of its length, the space between the exterior walls being 42 ft. and the height of each story 14 ft., the thickness of this wall should be $\frac{42+14}{36}=18$ in. 8 lines, instead of 18 in., which the architect assigned to it.

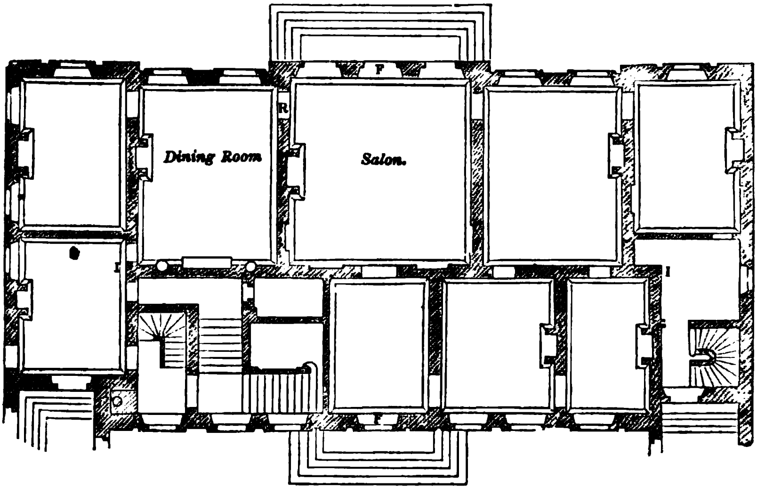


Fig. 608.

1561. By the same mode of operation, we shall find that the thickness of the wall R, separating the salon, which is 22 ft. wide, from the dining-room, which is 18 ft. wide and 14 ft. high, should be 18 in. and 6 lines instead of 18 inches; but as the exterior walls, which are of wrought stone, are 2 ft. thick, and their stability greater than the rule requires, the interior will be found to have the requisite stability without any addition to their thickness.

1562. We shall conclude the observations under this head, by reference to a house built by Palladio for the brothers Mocenigo, of Venice, to be found in his works, and here given (*fig.* 609.). Most of the buildings of this master are vaulted below; but the one in question is not in that predicament. The width and height of the principal rooms is 16 ft., and they are separated by others only 8 ft. wide, so that the width which each wall separates is 25¼ ft., and their thickness consequently should be $\frac{25\frac{1}{4}+16}{36}=13$ in. 10 lines. The walls, as executed,

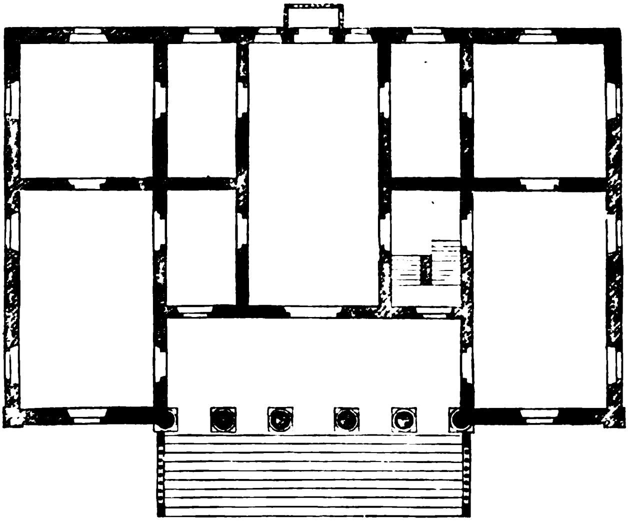


Fig. 609.

are actually 14 in. in thickness. The exterior walls being 24 ft. high, and the depth of the building 46 ft., their thickness by the rule should be 17½ in.; they are actually 18 in.

Of the Stability of Piers, or Points of Support.

1563. Let ABCD (*fig.* 610.) be a pier with a square base whose resistance is required to be known in respect of a power at M acting upon it to overturn it horizontally in the direction MA, or obliquely in that of NA upon the point D. To render the demonstration more simple, we will consider the solid reduced to a plane passing through G, the centre of gravity of the pier, and the point D, that upon which the power is supposed to cause it to turn. Letting fall from G the vertical cutting the base in I, to which we will suppose the weight of the pier suspended, and then supposing the pier removed, we shall only have to consider the angular lever BDI or HDI, whose arms are determined by perpendiculars drawn from the fulcrum D, in one direction vertical with the weight, and in the other perpendicular to the direction of the power acting upon the pier, according to the theory of the lever explained in a previous section.

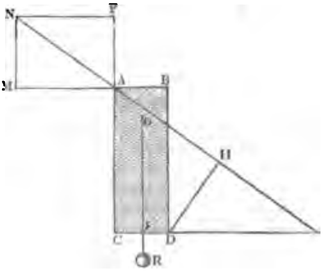


Fig. 610.

1564. The direction of the weight R being always represented by a vertical let fall from the centre of gravity, the arm of its lever ID never changes, whatever the direction of the power and the height at which it is applied, whilst the arm of the lever of the power varies as its position and direction. That there may be equilibrium between the effort of the power and the resistance of the pier, in the first case, when the power M acts in an horizontal direction, we have M : R :: ID : DB, whence $M \times DB = R \times ID$ and $M = \frac{R \times ID}{DB}$. If the direction of the power be oblique, as NA in the case of an equilibrium, N : R :: ID : DH; hence $N \times DH = R \times ID$ and $N = \frac{R \times ID}{DH}$.

1565. Applying this in an example, let the height of the pier be 12 ft., its width 4 ft., and its thickness 1 ft. The weight R of the pier may be represented by its cube, and is therefore $12 \times 4 \times 1 = 48$. The arm of its lever ID will be 2, and we will take the horizontal power M represented by DB at 12; with these values we shall have M : 48 :: 2 : 12; hence $M \times 12 = 48 \times 2$ and $M = \frac{48 \times 2}{12} = 8$.

That is, the effort of the horizontal power M should be equal to the weight of 8 cube feet of the materials whereof the pier is composed, to be in equilibrium.

1566. In respect of the oblique power which acts in the direction NA, supposing DH $= 7\frac{1}{3}$, we have N : 48 :: 2 : $7\frac{1}{3}$, whence $N \times 7\frac{1}{3} = 48 \times 2$, therefore $N = \frac{48 \times 2}{7\frac{1}{3}} = 13\frac{1}{3}$, whilst the expression of the hozirontal power M was only 8 ft.; but it must be observed, that the arm of the lever is 12, whilst that of the power N is but $7\frac{1}{5}$ ft.; but $13\frac{1}{3} \times 7\frac{1}{5} = 8 \times 12 = 96$, which is also equal to the resistance of the pier expressed by $12 \times 4 \times 2 = 96$. It is moreover essential to observe, that, considering the power NA as the result of two others, MA and FA, the first acting horizontally from M against A, tends to overthrow the pier; whilst the second, acting vertically in the direction FA, partly modifies this effect by increasing the resistance of the pier.

1567. Suppose the power NA to make an angle of 53 degrees with the vertical AF, and of 37 degrees with the horizontal line AM; then

NA : FA : MA::rad. : sin. 37 deg. : sin. 53 deg.::10 : 6 : 8.

Hence, NA being found $=13\frac{1}{3}$, we have $10 : 6 : 8 :: 13\frac{1}{3} : 8 : 10\frac{2}{3}$.

Whence it is evident that, from this resolution of the power NA, the resistance of the pier is increased by the effort of the power FA = 8, which, acting on the point A in the direction FA, will make the arm of its lever CD = 4, whence its effort $= 8 \times 4 = 32$.

1568. The resistance of the pier, being thus found = 96, becomes by the effort of the power FA = 96 + 32 = 128.

1569. The effort of the horizontal power M being $10\frac{2}{3}$, and the arm of its lever being always 12, its effort 128 will be equal to the resistance of the pier, which proves that in this resolution we have, as before, the effort and the resistance equal. The application of this proposition is extremely useful in valuing exactly the effects of parts of buildings which become stable by means of oblique and lateral thrusts.

1570. If it be required to know what should be the increased width of the pier to counterpoise the vertical effort EA, its expression must be divided by ID, that is, 8×2, which gives 4 for this increased length, and for the expression of its resistance $(12 + 4) \times 4 \times 2 = 128$, as above.

1571. If the effort of the power be known, and the thickness of a pier or wall whose height is known be sought so as to resist it, let the power and parts of the pier be represented by different letters, as follows. Calling the power p, the height of the pier d, the thickness sought x; if the power p act in an horizontal direction at the extremity of the wall or pier, its expression will be $p \times d$. The resistance of the pier will be expressed by its area multiplied by its arm of lever, that is, $d \times x \times \frac{x}{2}$; and supposing equilibrium, as the resistance must be equal to the thrust, we shall have the equation $p \times d = d \times x \times \frac{x}{2}$. Both sides of this equation being divisible by d, we have $p = x \times \frac{x}{2}$; and as the second term is divided by 2, we obtain $2p = x \times x$ or x^2; that is, a square whose area $= 2p$, and of which x is the side or root, or $x = \sqrt{2p}$, a formula which in all cases expresses the thickness to be given to the pier CD to resist a power M acting on its upper extremity in the horizontal direction MA.

1572. In this formula, the height of the pier need not be known to find the value of x, because this height, being common to the pier and the arm of the lever of the power, does not alter the result; for the cube of the pier, which represents its weight, increases or diminishes in the same ratio as the lever. Thus, if the height of the pier be 12, 15, or 24 ft., its thickness will nevertheless be the same.

Example. — If the horizontal power expressed by p in the formula $x = \sqrt{2p}$ be 8, we have $x = \sqrt{16} = 4$ for the thickness of the pier. Whilst the power acting at the extremity of the pier remains the same, the thickness is sufficient, whatever the height of the pier. Thus for a height of 12 ft. the effort of the power will be $8 \times 12 = 96$, and the resistance $12 \times 4 \times 2 = 96$. If the pier be 15 ft. high, its resistance will be $15 \times 4 \times 2 = 120$, and the effort of the power $8 \times 15 = 120$. Lastly, if the height be 24 ft., the resistance will be $24 \times 4 \times 2 = 192$, and the effort of the power $8 \times 24 = 192$.

1573. If the point on which the horizontal force acts is lower than the wall or pier, the difference may be represented by f; and then $p \times (d - f) = d \times x \times \frac{x}{2}$;

Which becomes $2pd - 2pf = dxx$ and $2p - \frac{2pf}{d} = xx$;

Lastly $x = \sqrt{2p - \frac{2pf}{d}}$.

Suppose $p = 9$. $f = 6$ and $d = 12$,

the formula becomes $x = \sqrt{18 - \frac{18 \times 6}{12}} = \sqrt{9} = 3$, which is the thickness sought.

1574. When the power NA is oblique, the thickness may be equally well found by the arm of lever DH, by resolving it into two forces, as before. Thus, in the case of the oblique power $p = 13\frac{1}{3}$, calling f its arm of lever $7\frac{1}{5}$, we shall have $p \times f = \frac{dxx}{2}$, which will become $\frac{2pf}{d} = xx$, whence $x = \sqrt{\frac{2pf}{d}}$; in which, substituting the known values, we have $x = \frac{\sqrt{2 \times 13\frac{1}{3} \times 7\frac{1}{5}}}{121}$; whence $x = \sqrt{16} = 4$, the thickness sought of the pier.

1575. In resolving the oblique effort NA into two forces, whereof one MA tends to overturn the pier by acting in an horizontal direction, and the other *f*A to strengthen it by acting vertically, as before observed; let us represent the horizontal effort MA by p, its arm of lever, equal to the height of the pier, by d, the vertical effort *f*A by n; the arm of lever of the last-named effort, being the thickness sought, will be x; from which we have the equation

$$pd=\frac{dxx}{2}+nx, \text{ or } 2p=xx+\frac{2nx}{d}.$$

1576. As the second member of this equation is not a perfect square, let there be added to each side the term wanting, that is, the square $\frac{nn}{dd}$, the half of the quantity $\frac{2n}{d}$, which multiplied x in the second term, whence

$$2p+\frac{nn}{dd}=xx+\frac{2nx}{d}+\frac{n}{d}.$$

1577. The second member, by this addition, having become a square whose root is $x+\frac{n}{d}$, we shall have $x+\frac{n}{d}=\sqrt{2p+\frac{nn}{dd}}$ and lastly $x=\sqrt{2p+\frac{nn}{dd}}-\frac{n}{d}$ will be the general formula for finding the thickness x.

Application of the Formula.

1578. Let $p=10\frac{2}{3}$, $n=8$, $d=12$. Substituting these values in the formula, it will become

$$x=\sqrt{10\tfrac{2}{3}\times 2+\tfrac{64}{144}}-\tfrac{8}{12}=\sqrt{21\tfrac{1}{3}+\tfrac{4}{9}}-\tfrac{2}{3}=\sqrt{21+\tfrac{7}{9}}-\tfrac{2}{3}=4.$$

1579. If, for proof, we wish to calculate the expression of the resistance, by placing in the equation of equilibrium $2pd=dx\frac{x}{2}\times nx$, the values of the quantities p, d, and x, above found, we shall have

$$10\tfrac{2}{3}\times 12=12\times 4\times 2+8=128, \text{ as was previously found for EA.}$$

1580. From the preceding rules, it appears that all the effects whose tendency is to destroy an edifice, arise from weight acting in an inverse ratio to the obstacles with which it meets. When heavy bodies are merely laid on one another, the result of their efforts is a simple pressure, capable of producing settlement or fracture of the parts acted upon.

1581. Foundations whose bases are spread over a much greater extent than the walls imposed upon them, are more susceptible of settlement than of crushing or fracture. But isolated points of support in the upper parts, which sometimes carry great weights on a small superficies, are susceptible both of settlement and crushing, whilst the weight they have to sustain is greater than the force of the materials whereof they are formed; which renders the knowledge of the strength of materials an object of consequence in construction. Till of late years it was not thought necessary to pay much attention to this branch of construction, because most species of stone are more than sufficiently hard for the greatest number of cases. Thus, the abundant thickness which the ancients generally gave to all the parts of their buildings, proves that with them this was not a subject of consideration; and the more remotely we go into antiquity, the more massive is the construction found to be. At last, experience taught the architect to make his buildings less heavy. Columns, which among the Egyptians were only 5 or 6 diameters high, were carried to 9 diameters by the Greeks in the Ionic and Corinthian orders. The Romans made their columns still higher, and imparted greater general lightness to their buildings. It was under the reign of Constantine, towards the end of the empire, that builders without taste carried their boldness in light construction to an extraordinary degree, as in the ancient basilicæ of St. Peter's at Rome and St. Paolo fuorì le murà. Later, however, churches of a different character, and of still greater lightness, were introduced by the Gothic architects.

1582. The invention and general use of domes created a very great load upon the supporting piers; and the earlier architects, fearful of the mass to be carried, gave their piers an area of base much greater than was required by the load supported, and the nature of the stone used to support it. They, moreover, in this respect, did little more than imitate one another. The piers were constructed in form and dimensions suited rather to the arrangement and decoration of the building that was designed, than to a due apportionment of the size and weight to the load to be borne; so that their difference from one another is in every respect very considerable.

The piers bearing the dome of St. Peter's at Rome are loaded with a weight of 14·964 tons for every superficial foot of their horizontal section.

The piers bearing the dome of St. Paul's at London are loaded with a weight of 17·705 tons for every superficial foot of their horizontal section.

The piers bearing the dome of the Hospital of Invalids at Paris are loaded with a weight of 13·598 tons for every superficial foot of their horizontal section.

The piers bearing the dome of the Pantheon (St. Geneviéve) at Paris are loaded with a weight of 26·934 tons for every superficial foot of their horizontal section.

The columns of St. Paolo fuori le mura, near Rome, are loaded with a weight of 18·123 tons for every superficial foot of their horizontal section.

In the church of St. Méry, the piers of the tower are loaded with upwards of 27 tons to the superficial foot. With such a discrepancy, it is difficult to say, without a most perfect knowledge of the stone employed, what should be the exact weight per foot. The dome of the Hospital of the Invalids seems to exhibit a maximum of pier in relation to the weight, and that of the Pantheon at Paris a minimum. All the experiments (scanty, indeed, they are) which we can present to the reader are those given at the beginning of this section. In this country, the government has always been too much employed in considering how long it can keep itself in place, to have time to consider how the services of its members could benefit the nation by the furtherance of science. An exactly opposite conduct has always marked the French government: hence more scientific artists are always found amongst them than we can boast here, where the cost of experiments invariably comes out of the artist's pocket.

Ratio of the Points of Support in a Building to its total Superficies.

1583. In the pages immediately preceding, we have, with Rondelet for our guide, explained the principles whereon depend the stabilities of walls and points of support, with their application to different sorts of buildings. Not any point relating to construction is of more importance to the architect. Without a knowledge of it, and the mode of even generating new styles from it, he is nothing more than a pleasing draughtsman at the best, whose elevations and sections may be very captivating, but who must be content to take rank in about the same degree as the portrait painter does in comparison with him who paints history. Hereafter will be given the method of properly covering the walls, one which has occupied so much of our space; namely, when we treat of the subject of Roofs, and the method of framing them. It is equally important, and of as high value to the architect, as that which we are now quitting, to which we regret our limits do not allow us to add more: but previous to leaving it, we must subjoin a table of great instruction, showing the ratio of the points of support to the total superficies covered in some of the principal buildings of Europe.

Table showing the Ratio of the Walls and Points of Support of the principal Edifices of Europe to the total Area which they occupy.

Names of Edifices.	Total Area of the Building in English superficial feet.	Total Area of the Points of Support in English superficial feet.	Ratio in Thousandths of the Points of Support to the total Area.
The Pantheon at Rome - - -	34,328	7,954	0·232
Temple of Peace at Rome - - -	67,123	8,571	0·127
Great temple at Pæstum - - -	15,353	2,649	0·172
Ancient temple, Galuzzo, at Rome - -	9,206	2,167	0·235
Temple of Concord, Girgenti, Sicily - -	6,849	1,330	0·194
Temple of Juno Lucina, Sicily - -	6,821	1,110	0·163
Central building of the baths of Caracalla -	275,503	48,911	0·176
Central building of the baths of Diocletian -	351,636	58,797	0·167
Temple of Claudius at Rome, now church of S. Stefano - - - - - -	36,726	2,051	0·056
Mosque of S. Sophia at Constantinople -	103,200	22,567	0·217
Basilica of S. Paolo fuorì le murà (Rome), 1816 - - - - - -	106,513	12,655	0·118
Duomo of S. Maria del fiore at Florence -	84,802	17,030	0·201
Duomo of S. Maria del fiore at Milan -	125,853	21,635	0·169
St. Peter's at Rome, as executed - -	227,069	59,308	0·261
St. Peter's at Rome, as projected by Bramante	213,610	46,879	0·219
Church of S. Vitale at Ravenna - -	7,276	1,142	0·157
Church of S. Pietro a Vincolà, Rome - -	21,520	3,353	0·155
Church of S. Sabino — destroyed - -	15,139	1,543	0·100
Church of S. Domenico, Palermo - -	34,144	4,988	0·146
Church of S. Giuseppe, Palermo - -	26,046	3,611	0·139
Church of S. Filippo Neri, Naples - -	22,826	2,944	0·129
Church of St. Paul's, London - -	84,025	14,311	0·170
Church of Notre Dame, Paris - -	67,343	8,784	0·140
Hotel of the Invalids, Paris - - -	29,003	7,790	0·268
Church of S. Sulpice, Paris - - -	60,760	9,127	0·151
Church of S. Geneviéve, Paris - -	60,287	9,269	0·154

The above table exhibits also the comparative sizes of the different buildings named in it.

Pressure of Earth against Walls.

1584. It is not our intention to pursue this branch of the practice of walling to any extent, the determination of the thickness of walls in this predicament being more useful, perhaps, to the engineer than to the architect. We shall therefore be contented with but a concise mention of it. Rondelet has (with, as we consider, great judgment) adopted the theory of Belidor, in his *Science des Ingenieurs*, and we shall follow him. Without the slightest disrespect to later authors, we know from our own practice that walls of *Revêtement* may be built, with security, of much less thickness than either the theories of Belidor, or, latterly, of modern writers require. We entirely leave out of the question the rules of Dr. Hutton in his Mathematics, as absurd and incomprehensible. The fact is, that in carrying up walls to sustain a bank of earth, nobody, in the present day, would dream of constructing them without carefully ramming down the earth, layer by layer, as the wall is carried up, so as to prevent the weight of the earth, in a triangular section, pressing upon the wall, which is the foundation of all the theory on the subject. With this qualification, therefore, we shall proceed; premising, that if the caution whereof we speak be taken, the thickness resulting from the following investigations will be much more than the outside of enough.

1585. Earth left to itself takes a slope proportionate to its consistence; but for our purpose it will sufficiently exhibit the nature of the investigation, to consider the substance pressing against the wall as dry sand or pounded freestone, which will arrange itself in a slope of about 55½° with the vertical plane, and therefore of 34½° with an horizontal plane, as Rondelet found to be the case when experimenting on the above materials in a box, one of whose sides was removable. Ordinarily, 45° is taken as the mean slope into which earths recently thrown up will arrange themselves.

1536. Belidor, in order to form an estimate for the thrust or pressure into which we are inquiring, divides the triangle EDF (*fig.* 611.) representing the mass of earth which creates the thrust, by parallels to its base ED, forming slices or sections of equal thickness and similar form; whence it follows, that, taking the first triangle *a*F*b* as unity, the second slice will be 3, the third 5, the fourth 7, and so on in a progression whose difference is 2.

1587. Each of these sections being supposed to slide upon an inclined plane parallel to ED, so as to act upon the face FD, if we multiply them by the mean height at which they collectively act, the sum of the products will give the total effort tending to overturn the wall; but as this sum is equal to the product of the whole triangle by the height determined by a line drawn from its centre of gravity parallel to the base, this last will be the method followed, as much less complicated than that which Belidor adopts, independent of some of that author's suppositions not being rigorously correct.

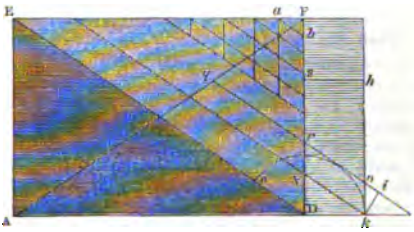


Fig. 611.

1588. The box in which the experiment was tried by Rondelet was 16½ in. (French) long, 12 in. wide, and 17½ in. high in the clear. As the slope which the pounded freestone took when unsupported in front formed an angle with the horizon of 34½°, the height AE is 11⅓, so that the part acting against the front, or that side of the box where would be the wall, is represented by the triangle EDF.

1589. To find by calculation the value of the force, and the thickness which should be given to the opposed side, we must first find the area of the triangle EDF $= \frac{16\frac{1}{2} \times 11\frac{1}{3}}{2} = 93\frac{1}{2}$; but as the specific gravity (or equal mass) of the pounded stone is only $\frac{13}{15}$ of that of the stone or other species of wall which is to resist the effort, it will be reduced to $73\frac{1}{2} \times \frac{13}{15} = 81$. This mass being supposed to slide upon the plane ED, its effort to its weight will be as AE is to ED :: $11\frac{1}{3} : 20$, or $81 \times \frac{11\frac{1}{3}}{20} = 45{\cdot}9$, which must be considered as the oblique power *qr* passing through the centre of gravity of the mass, and acting at the extremity of the lever *ik*. To ascertain the length of the lever, upon whose length depends the thickness of the side which is unknown, we have the similar triangles *qsr*, *qho*, and *kio*, whose sides are proportional: whence $qs : sr :: qh : ho$; and as $ko = hk - ho$, we have $qr : rs :: hk - ho : if$.

$$\text{Whence, } if = \frac{(hk - ho) \times qs}{qr},$$

The three sides of the triangle *qsr* are known from the position of the angle *q* at the centre of gravity of the great triangle EFD, whence each of the sides of the small triangle is equal to one third of those of the larger one, to which it is correspondent.

Thus, making the side $qr = a$,
$qs = b$,
$rs = c$,
The unknown side $sh = x$,
$hk = f$,
The pressure 45·9 found $= p$,
The height DF $= d$,
We have $b : c :: b + x : \frac{bc+cx}{b} = ho$, and $hk - ho$ will be $f - \frac{bc+cx}{b}$.

To obtain ik, we have the proportion $a : b :: f - \frac{bc-cx}{b} : ik$.

Whence $ik = \frac{bf-bc-cx}{a}$; so that the pressure $p \times ik$ is represented by $p\left(\frac{bf-bc-cx}{a}\right)$, to which the resistance expressed by $\frac{dx^2}{2}$ must equilibrate.

Thus the equation becomes $\frac{dx^2}{2} = p\left(\frac{bf-bc-cx}{a}\right)$, or $x^2 + \frac{2pcx}{ad} = \frac{2p(bf-bc)}{ad}$.

For easier solution, make $\frac{2pbf-2pbc}{ad} = 2m$, and $\frac{2pc}{ad} = 2n$, and we have $x^2 + 2nx = 2m$, an equation of the second degree, which makes $x = \sqrt{2m + nn} - n$, which is a general formula for problems of this sort.

Returning to the values of the known quantities, in which

$$a = 6\tfrac{2}{3} \qquad f = 7\tfrac{1}{3}$$
$$b = 5\tfrac{1}{2} \qquad p = 45\tfrac{9}{10}$$
$$c = 3\tfrac{3}{4} \qquad d = 11\tfrac{1}{3}$$

$$m = pb \times \frac{f-c}{ad} \text{ becomes } m = 45·9 \times 5\tfrac{1}{2} \times \frac{7\tfrac{1}{3} - 3\tfrac{3}{4}}{6\tfrac{2}{3} + 11\tfrac{1}{3}} = 12·70 \text{ and } 2m = 25·4\,;$$

$$n = \frac{pc}{ad} \text{ becomes } n = \frac{45·9 \times 3·75}{75·55} = 2·28 \text{ and } nn = 5·20.$$

From the above, then, the formula $x = \sqrt{2m + nn} - n$ becomes $x = \sqrt{25·4 + 5·20} - 2·28 = 3·22$, a result which was confirmed by the experiment, inasmuch as a facing of the thickness of 3¼ inches was found necessary to resist the pressure of pounded freestone. By Belidor's method, the thickness comes out 4 8/10 inches; but it has been observed that its application is not strictly correct. In the foregoing experiment, the triangular part only of the material in the box was filled with the pounded stone, the lower part being supposed of material which could not communicate pressure. But if the whole of the box had been filled with the same material, the requisite thickness would have been found to be 5¼ inches to bear the pressure.

1590. In applying the preceding formula to this case, we must first find the area of the trapezium BEDF (*fig.* 612.), which will be found 195⅓; multiplying this by 13/15, to reduce the retaining wall and the material to the same specific gravity, we have 169⅓. This mass being supposed to slide upon the inclined plane ED, its effort parallel to that plane will be $195\tfrac{1}{3} \times \frac{11\tfrac{1}{3}}{20} = 95·76 = p$. Having found in the last formula that qs is represented by $b = 6·93$, sr by $c = 4·76$, qr by $a = 8·40$, $f = 11·3$, $d = 17·5$; the thickness of the retaining wall becomes $= sh - x$; $m = pb \times \frac{f-c}{ad}$ will become, substituting the values $95·76 \times 6·93 \times \frac{11·3-4·76}{8·40 \times 17·50} = 29·52$ and $2m = 59·04$. $n = \frac{pc}{ad}$ becomes $\frac{95·76 \times 4·76}{8·40 \times 17·50} = 3·1$, and $nn = 9·61$. Substituting these values in the formula $x = \sqrt{2m + nn} - n$, we have $x = \sqrt{59·04 + 9·61} - 3·1 = 5·2$, a result very confirmatory of the theory.

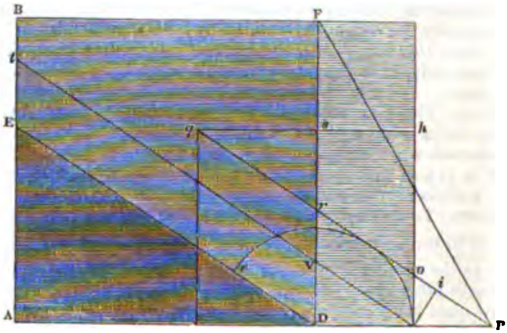


Fig. 612.

1591. In an experiment made on common dry earth, reduced to a powder, which took a slope of 46° 50′, its specific gravity being only ¾ of that of the retaining side, it was found that the thickness necessary was 3 inches 6/10.

1592. It is common, in practice, to strengthen walls for the retention of earth with piers at certain intervals, which are called *counterforts*, by which the wall acquires additional strength; but after what we have said in the beginning of this article, on the dependence that is to be placed rather on well ramming down each layer of earth at the back of the wall, supposing it to be of ordinary thickness, we do not think it necessary to enter upon any calculation relative to their employment. It is clear their use tends to diminish the requisite thickness of the wall, and we would rather recommend the student to apply himself to the knowledge of what has been done, than to trust to calculation for stability, though we think the theory ought to be known by him.

Sect. XI.

MECHANICAL CARPENTRY.

1593. The woods used for the purposes of carpentry merit our attention from their importance for the purpose of constructing solid and durable edifices. They are often employed to carry great weights, and to resist great strains. Under these circumstances, their strength and dimensions should be proportioned to the strains they have to resist. For building purposes, oak and fir are the two sorts of timber in most common use. Stone has, doubtless, the advantage over wood: it resists the changes of moisture and dryness, and is less susceptible of alteration in the mass; hence it ensures a stability which belongs not to timber. The fragility of timber is, however, less than that of stone, and its facility of transport is far greater. The greatest inconvenience attending the use of timber, is its great susceptibility of ignition. This has led, in this as in every age, to expedients for another material, and in public buildings the object may be attained. In private buildings, the cost of the substitute will not permit the employment of other than the material which is the subject of our section.

1594. Oak is one of the best woods that can be employed in carpentry. It has all the requisite properties; such as size, strength, and stiffness. Oaks are to be found capable of furnishing pieces 60 to 80 ft. long, and 2 ft. square. In common practice, beams rarely exceed 36 to 40 ft. in length, by 2 ft. square.

1595. In regard to its durability, oak is preferable to all other trees that furnish equal lengths and scantlings: it is heavier, better resists the action of the air upon it, as well as that of moisture and immersion in the earth. It is a saying relating to the oak, that it grows for a century, lasts perfect for a century, and takes a century to perish. When cut at a proper season, used dry, and protected from the weather, it lasts from 500 to 600 years. Oak, like other trees, varies in weight, durability, strength, and density, according to the soil in which it grows. The last is always in an inverse proportion to the slowness of its growth; trees which grow slowest being invariably the hardest and the heaviest.

1596. From the experiments made upon oak and other sorts of wood, it is found that their strength is proportional to their density and weight; that of two pieces of the same species of wood, of the same dimensions, the heavier is usually the stronger.

1597. The weight of wood will vary in the same tree; usually the heaviest portions are the lower ones, from which upwards a diminution of weight is found to occur. In full-grown trees, however, this difference does not occur. The oak of France is heavier than that of England; the specific gravity of the former varying from 1000 to 1054, whilst the latter, in the experiments of Barlow, varies from 770 to 920. The weight, therefore, of an English cube foot of French oak is about 58 English pounds. Timber may be said to be well seasoned when it has lost about a sixth part of its weight.

1598. In carpentry, timber acts with an absolute and with a relative strength. For instance, that called the absolute strength is measured by the effort that must be exerted to break a piece of wood by pulling it in the direction of the fibres. The relative strength of a piece of wood depends upon its position. Thus a piece of wood placed horizontally on two points of support at its extremities, is easier broken, and with a less effort, than if it was inclined or upright. It is found that a smaller effort is necessary to break the piece as it increases in length, and that this effort does not decrease strictly in the inverse ratio of the length, when the thicknesses are equal. For instance, a piece 8 ft. long, and 6 in. square, placed horizontally, bears a little more than double of another, of the same depth and thickness, 16 ft. long, placed in the same way. In respect of the absolute force, the difference does not vary in the same way with respect to the length. The following are experiments by Rondelet, to ascertain the absolute force, the specimen of oak being of 861 specific gravity, and a cube foot, therefore, weighing $49\frac{1}{10}$ lbs.

Cohesive Force of Pieces drawn in the Direction of their Length.

First experiment.

A small rod of oak 0·0888 in. (= 1 French line) square, and 2·14 in. in length, broke with a weight of - - - 115 lbs. averdupois.
Another specimen of the same wood, and of similar dimensions, broke with - - - - - - $105\frac{8}{10}$
Another specimen - - - - - - $110\frac{1}{10}$
The mean weight, therefore, was, in round numbers, 110 lbs.
A rod of the same wood as the former, 0·177 inch (=2 French lines) square, and 2·14 inches long, broke with a weight of - $439\frac{1}{4}$ lbs. averdupois.
Another specimen - - - - - - 418
Another specimen - - - - - - $451\frac{1}{4}$
The mean weight, therefore, was 436 lbs. for an area $\frac{35}{1000}$ in. (= 4 square lines French, or 110 lbs. for each, French line = 0·0888 in. English).

1599. Without a recital of all the experiments, we will only add, that after increasing the thickness and length of the rods in the several trials, the absolute strength of oak was found to be 110 lbs. for every $\frac{888}{10000}$ of an inch area (=1 French line superficial).

The Strength of Wood in an upright Position.

1600. If timber were not flexible, a piece of wood placed upright as a post, should bear the weights last found, whatever its height; but experience shows that when a post is higher than six or seven times the width of its base, it bends under a similar weight before crushing or compressing, and that a piece of the height of 100 diameters of its base is incapable of bearing the smallest weight. The proportion in which the strength decreases as the height increases, is difficult to determine, on account of the different results of the experiments. Rondelet, however, found, after a great number, that when a piece of oak was too short to bend, the force necessary to crush or compress it was about 49·72 lbs. for every $\frac{888}{10000}$ of a square inch of its base, and that for fir the weight was about 56·16 lbs. Cubes of each of these woods, on trial, lost height by compression, without disunion of the fibres; those of oak more than a third, and those of fir one half.

1601. A piece of fir or oak diminishes in strength the moment it begins to bend, so that the mean strength of oak, which is 47·52 lbs. for a cube $\frac{888}{10000}$ of an inch, is reduced to 2·16 lbs. for a piece of the same wood, whose height is 72 times the width of its base. From many experiments, Rondelet deduced the following progression: —

For a cube, whose height is 1, the strength = 1
— — 12, — $=\frac{5}{6}$
— — 24, — $=\frac{1}{2}$
— — 36, — $=\frac{1}{3}$
— — 48, — $=\frac{1}{6}$
— — 60, — $=\frac{1}{12}$
— — 72, — $=\frac{1}{24}$

Thus, for a cube of oak, whose base is 1·066 in. area (=1 square in. French) placed upright, that is, with its fibres in a vertical direction, its mean strength is expressed by 144* × 47·52 = 6842 lbs. From a mean of these experiments, the result was (by experiment) in lbs. averdupois - - - - 6853
For a rod of the same oak, whose section was of the same area by 12·792 in. high (=12 French in.), the weight borne or mean strength is $144 \times \frac{47{\cdot}52 \times 5}{6} = 5702$ lbs.
From a mean of three experiments, the result was - - - 5735
For a rod 25·584 (=24 French) in. high, the strength is $144 \times \frac{47{\cdot}52}{2} = 3421$ lbs. - 3144
For a rod 38·376 (=36 French) in. high, the strength is $144 \times \frac{47{\cdot}52}{3} = 2281$ lbs. - 2336
For a rod 51·160 (=48 French) in. high, the strength is $144 \times \frac{47{\cdot}52}{6} = 1140$ lbs.
For a rod 63·960 (=60 French) in. high, the strength is $144 \times \frac{47{\cdot}52}{12} = 570$ lbs.
For a rod 76·752 (=72 French) in. high, the strength is $144 \times \frac{47{\cdot}52}{24} = 285$ lbs.
For a cube of fir, whose sides are 1·066 in. area (=1 square in. French), placed as before, with the fibres in a vertical direction, we have 144 × 56·16 = 8087 lbs. - 8089

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* The French inch, consisting of 144 lines.

For a square rod, whose base was 1·066 in. area (=1 square in. French), 12·792 in. high, we have $144 \times \frac{56\cdot16 \times 5}{6} = 6739$ lbs. - - - - 6863

For a rod 25·584 (=24 French) in. high, $144 \times \frac{56\cdot16}{2} = 4043$ lbs. - - 3703

For a rod 38·376 (=36 French) in. high, $144 \times \frac{56\cdot16}{3} = 2696$ lbs. - - 2881

For a rod 51·160 (=48 French) in. high, $144 \times \frac{56\cdot16}{6} = 1348$ lbs.

For a rod 63·960 (=60 French) in. high, $144 \times \frac{56\cdot16}{12} = 674$ lbs.

For a rod 76·752 (=72 French) in. high, $144 + \frac{56\cdot16}{24} = 337$ lbs.

The rule by Rondelet above given was that also adopted by MM. Perronet, Lamblardie, and Girard. In the analytical treatise of the last-named, some experiments are shown, which lead us to think it not very far from the truth. From the experiments, moreover, we learn, that the moment a post begins to bend, it loses strength, and that it is not prudent, in practice, to reduce its diameter or side to less than one tenth of its height.

1602. In calculating the resistance of a post after the rate of only 10·80 for every 1·066 superficial line English (=1 line super. French), which is much less than one quarter of the weight under which it would be crushed, we shall find that a square post whose sides are 1·066 ft. (=1 ft. French) containing 22104·576 English lines (=20736 French), would sustain a weight of 238729 lbs. or 106 tons. Yet as there may be a great many circumstances, in practice, which may double or triple the load, it is never safe to trust to a post the width of whose base is less than a tenth part of its height, to the extent of 5 lbs. per 1·066 line; in one whose height is fifteen times the width of the base, 4 lbs. for the same proportion; and when twenty times, not more than 3 lbs.

Horizontal Pieces of Timber.

1603. In all the experiments on timber lying horizontally, as respects its length, and supported at the ends, it is found that, in pieces of equal depth, their strength diminishes in proportion to the bearing between the points of support. In pieces of equal length between the supports, the strength is as their width and the squares of their depths. We here continue M. Rondelet's experiments.

1604. A rod of oak 2·132 in. (2 in. French) square, and 25·584 in. (24 in. French) long, broke under a weight of 2488·32 lbs., whilst another of the same dimensions, but 19·188 in. (18 in. French) bore 3353·40; whence it appears that the relative strength of these two rods was in the inverse ratio of their length. The proportion is 19·188 : 25·584 :: 2488·32 : 3317·76, instead of 3353·40 lbs., the actual weight in the experiment.

1605. In another rod of the same wood, 2·132 in. wide and 3·198 deep, and 25·584 in. bearing, it broke with a weight of 5532 lbs. In the preceding first-mentioned experiment it was found that a rod of 2·132 in. square, with a bearing 25·584 in. bore 2488·32 lbs. Supposing the strength of the rods to be exactly as the squares of their heights, we should have 4·54 ($2\cdot132^2$) : 10·23 ($3\cdot198^2$) :: 2488·32 : 5598·7 lbs.; which the second rod should have borne, instead of 5532 lbs. There are numberless considerations which account for the discrepancy, but it is one too small to make us dissatisfied with the theory.

1606. In a third experiment on the same sort of wood, the dimension of 3·198 in. being laid flatwise, and the 2·132 in. depthwise, the bearing or distance between the supports being the same as before, it broke with a weight of 3573 lbs.: whence it follows that the strength of pieces of wood of the same depth is proportional to their width. Thus, comparing the piece 2·132 in. square, which bore 2488 lbs., we ought to have 2·132 : 3·198 :: 2488·32 : 3624·48, instead of 3573 lbs.

1607. From a great number of experiments and calculations made for the purpose of finding the proportion of the absolute strength of oak, to that which it has when lying horizontally between two points of support, the most simple method is to multiply the area of the piece in section by half the absolute strength, and to divide the product by the number of times its depth is contained in the length between the points of support.

1608. Thus, in the experiments made by Belidor on rods of oak 3 French (=3·198 English) ft. long, and 1 French (=1·066 in. English) in. square, the mean weight under which they broke was 200·96 lbs. averdupois. Now, as the absolute strength of oak is from 98 to 110 lbs. for every $\frac{888}{100000}$ in. (=1 French line), the mean strength will be 104 and 52 lbs. for its half, and the rule will become (144 lines, being =1 French in.) $\frac{144 \times 52}{36\ (\text{F. in.})} = 207\cdot30$ lbs., instead of 200·96 lbs.

1609. Three other rods, 2 French in. square (2·132 Eng.), and of the same length between the supports, broke with a mean weight of 1711·8 lbs. By the rule $\frac{576(=144 \times 4) \times 52}{18} = 1658\cdot88$ lbs. averdupois. Without further mention of the experiments of Belidor, we may observe, that those of Parent and others give results which confirm the rule. The experiments, however, of Buffon, having been made on a larger scale, show that the strength of pieces of timber of the same size, lying horizontally, does not diminish exactly in the proportion of their length, as the theory whereon the rule is founded would indicate. It becomes, therefore, proper to modify it in some respects.

1610. Buffon's experiments show that a beam as long again as another of the same dimensions will not bear half the weight that the shorter one does. Thus —

A beam, 7·462 ft. long, and 5·330 in. square, broke with a weight of - - - - - -	12495·06	lbs. averdupois.
Another, 14·924 ft. long, of the same dimensions, broke with a weight of - - - - - -	5819.04	
A third, 29·848 ft. long, of the same dimensions, bore before breaking - - - - - -	2112·48	
By the rule, the results should have been, for the 7·462 ft. beam	12495·60	
for that of 14·924 -	6247·80	
for that of 29·848 -	3123·90	

Whence it appears, that owing to the elasticity of the timber, the strength of the pieces, instead of forming a decreasing geometrical progression, whose exponent is the same, forms one in which it is variable. The forces in question may be represented by the ordinates of a species of catenarean curve.

1611. In respect, then, of the diminution of the strength of wood, it is not only proportioned to the length and size, but is, moreover, modified in proportion to its absolute or primitive force and its flexibility; so that timber exactly of the same quality would give results following the same law, so as to form ordinates of a curve, exhibiting neither inflection nor undulation in its outline: thus in pieces whose scantlings and lengths form a regular progression, the defects can only be caused by a difference in their primitive strength; and as this strength varies in pieces taken from the same tree, it becomes impossible to establish a rule whose results shall always agree with experiment; but by taking a mean primitive strength, we may obtain results sufficiently accurate for practice. For this purpose, the rule that nearest agrees with experiment is —

1st. To subtract from the primitive strength one third of the quantity which expresses the number of times that the depth is contained in the length of the piece of timber.

2d. To multiply the remainder thus obtained by the square of the length.

3d. To divide the product by the number expressing the relation of the depth to the length.

Hence calling the primitive strength - - - $= a$
— the number of times that the depth is contained in the length $= b$
— the depth of the piece - - - $= d$
— the length - - - - $= l$

The general formula will be, $\dfrac{a - \frac{b}{3} \times dd}{b} = \dfrac{add}{b} - \dfrac{dd}{3}$.

1612. Suppose the primitive strength $a = 64·36$ for each 1·136 square line ($=1$ line French), we shall find for a beam 5·330 in. square, by 19·188 ft. long, or 230·256 inches, that the proportion of the depth to the length $= \frac{230·256}{5·330} = 43·2 = b$.

1613. The vertical depth being 5·330 or 63·960 lines, dd will be 4089·88; substituting these values in the formula $\frac{a \times dd}{b} - \frac{dd}{3}$ we have $\frac{64·36 \times 4089·88}{43·2} - \frac{4089·88}{3} = 4067·99$, instead of 4120·20, the mean result of two beams of the same scantlings in the experiments of Buffon. But as the mean primitive strength of the beams is, according to the second of the following tables, 64·99, instead of 64·36, which has been taken for the mean strength of all the pieces given in that table, we ought to have found less. Thus taking 64·99, we have $\frac{64·99 \times 4089·88}{43·2} - \frac{4089·88}{3} = 4120·20$, as in the experiment.

The scientific world generally, the architect and engineer especially, are indebted to the person from whom the tables which follow have emanated. They are worth more than all which hitherto has been done in this country; and our surprise is great that in most of the various treatises on timber and carpentry, some whereof have resulted from no mean hands, more importance has been given to theoretical instruction than to that which might have been deduced from experiments. The treatises, indeed, on mechanical carpentry almost seem to have been written more with the view of perplexing than of assisting the student.

TABLES OF EXPERIMENTS.

Table I.

Experiments on Pieces of Timber 4·264 inches square, supposing the absolute Strength 60·1344.

Length of the Pieces in Feet.	Proportion of Depth to Length.	Weight of the Pieces in Pounds.	Curvature before breaking, in Inches.	Absolute Strength.	Relative Strength.	Weight in Pounds averdupois.	Mean Effort according to Experiment.	Relative Strength according to Calculation.	Breaking Weight calculated on relative Strength.
				From Experiment.					
7·462	21	64·80 60·48	3·721 4·797	60·13	52·57	5778 5697	5768	52·57	5768
8·528	24	73·44 69·04	3·997 4·975	60·29	51·55	4968 4860	4869	51·49	4943
9·594	27	83·16 76·68	5·152 5·863	59·40	49·68	4428 4266	4387	50·41	4301
10·660	30	90·72 88·56	6·218 6·929	62·16	51·36	3715 3884	3946	49·33	3799
12·792	36	108·00 105·84	7·462 7·462	63·28	51·22	3294 3159	3279	47·17	3018

Table II.

Experiments on Pieces of Timber 5·330 inches square, supposing the absolute Strength 64·36.

7·462	16⅘	101·52 95·58	2·665 2·665	64·37	58·32	12,717 12,177	12,496	58·31	12,496
8·528	19⅕	112·32 110·16	2·842 3·109	63·58	56·67	10,692 10,449	10,626	57·34	10,750
9·594	21⅗	127·44 125·28 124·20	3·198 3·464 3·731	62·20	54·42	9,072 8,991 8,856	8,635	56·58	9,429
10·660	24	142·56 140·40 138·78	3·375 3·731 4·264	60·40	51·76	7,803 7,614 7,668	7,765	55·72	8,357
12·792	28⅘	168·48 166·32	5·886 6·132	63·50	51·54	6,534 6,588	6,644	54·99	6,748
14·924	33⅗	192·24 190·08	8·528 8·794	66·42	54·32	5,832 5,616	5,819	52·26	4,600
17·056	38⅖	225·72 221·40	8·616 8·705	65·12	51·30	4,779 4,617	4,810	50·53	4,738
19·188	43⅕	250·56 249·48	8·528 8·705	64·99	49·44	4,050 3,942	4,120	48·80	4,066
21·320	48	284·04 279·72	9·416 10·660	65·60	48·32	3,537 3,429	3,624	47·08	3,530
23·452	52⅘	303·48	11·992	68·34	49·33	3,213	3,364	45·35	3,092
25·584	57⅗	334·80 331·56	11·726 14·491	60·76	40·02	2,376 2,295	2,502	43·62	2,726
29·848	67⅕	393·12 388·80	19·188 23·452	63·42	39·24	1,944 1,890	2,112	40·16	2,151

Table III.

Experiments on Pieces of Timber 6·396 inches square, supposing the absolute Strength 56·88.

7·462	14	138·24 136·62	2·132 2·132	60·44	54·50	20,790 20,142	20,635	51·84	9156
8·528	16	160·92 157·68	2·487 2·576	57·75	52·28	16,956 16,578	16,804	51·12	15,562
9·594	18	179·28 177·66	2·664 3·020	56·09	49·61	14,526 13,878	14,292	50·40	14,547
10·660	20	203·04 200·88	3·198 3·430	54·23	47·05	12,393 11,907	12,197	49·68	12,877

TABLE III. — *continued.*

Length of the Pieces in Feet.	Proportion of Depth to Length.	Weight of the Pieces in Pounds.	Curvature before breaking, in Inches.	Absolute Strength.	Relative Strength.	Weight in Pounds averdupois.	Mean Efforts according to Experiment.	Relative Strength according to Calculation.	Breaking Weight calculated on relative Strength.
				From Experiment.					
12·792	24	241·92 238·68	4·264 4·352	54·69	46·05	9,936 9,720	9,938	48·24	9,420
14·924	28	275·40 274·32	4·797 4·441	54·36	44·28	7,766 8,100	8,210	46·81	8,666
17·056	32	317·52 316·48	5·863 6·218	54·86	43·38	6,750 6,993	7,030	45·36	7,348
19·188	36	360·72 357·48	7·906 9·060	54·92	42·96	6,075 5,940	6,187	43·92	6,319
21·320	40	407·16 405·00	10·126 9·416	56·79	42·39	5,427 5,259	5,495	42·49	5,506

TABLE IV.

Experiments on Pieces of Timber 7·462 inches square, supposing the absolute Strength 57·85.

8·528	13 5/7	220·32 217·62	2·931 2·664	59·82	54·88	28,242 28,026	28,243	52·92	26,927
9·594	15 3/7	245·16 243·00	3·286 3·109	58·59	53·04	27,599 23,652	24,260	51·74	23,656
10·660	17 1/7	274·32 272·16	2.753 3·198	57·60	51·43	21,222 20,844	21,169	51·68	21,246
12·792	20 4/7	326·16 325·08	3·109 3·553	58·80	51·41	18,144 16,794	17,633	50·49	17,318
14·924	24	379·08 379·08	4·441 3·997	57·85	49·21	14,688 13,878	14,472	49·21	14,470
17·056	27 3/7	438·48 435·24	5·152 5·596	56·94	47·07	11,988 11,772	12,098	47·98	12,343
19·188	30 6/7	491·32 491·32	5·863 6·218	56·69	45·49	10,106 10,152	10,424	46·76	10,693
21·320	34 2/7	545·40 540·00	8·350 9·060	57·09	44·74	8,914 8,640	9,208	45·51	9,207

TABLE V.

Experiments on Pieces of Timber 8·528 inches square, supposing the absolute Strength 55·08.

10·660	15	357·48 357·48	3·198 2·398	54·46	49·06	30,024 29,916	30,148	49·68	30,363
12·792	18	428·76 427·14	3·198 3·109	56·35	49·87	25,812 24,840	25,540	48·60	24,883
14·924	21	497·88 495·72	4·086 3·375	56·78	49·23	21,654 21,060	21,605	47·52	20,854
17·056	24	570·24 565·92	5·407 6·129	55·42	46·78	18,144 17,117	17,968	46·44	17,833
19·188	27	641·52 639·64	4·797 4·352	52·42	42·70	14,580 13,932	14,577	45·36	15,482
21·320	30	717·12 712·80	7·995 6·396	54·10	43·30	11,717 13,176	13,303	44·28	13,593

1614. The five preceding tables give a view of the results of experiments by Buffon upon beams 4·264, 5·330, 6·396, 7·462, and 8·528 inches square, of different lengths, as compared with those found by the modified rule above given (1660.).

1615. The first column shows the length of the pieces in English feet. The second, the proportion of their depth to their length. The third, the weight of each piece in pounds averdupois. The fourth, the weight borne before breaking. The fifth, the absolute or primitive strength, that is, independent of the length. The sixth, that strength reduced in the ratio of the proportion of the depth to the length of the pieces given in the second column. The seventh column gives the weight borne before breaking, independent of their own weight. The eighth, the mean effort with which the pieces broke, including half their weight, the other half acting on the points of support. The ninth shows the reduced strength of the pieces in respect of the proportions of the depth to the length, supposing the primitive strength equal for all the pieces in the same table. The tenth column gives the result of the calculation according to the rule above given.

1616. In order to give an idea of the method of representing the strength of wood of the same scantling, but of different lengths, by the ordinates of a curve, we annex *fig.* 612. to explain by it the result of the experiments of Buffon, given in the second table. The ordinates of the polygon N, O, P, Q, &c. represent the results of the experiments made upon beams 5·330 in. square, of different lengths, whose primitive strength varied in each piece.

1617. The ordinates of the regular curve, *m*, *l*, *i*, *h*, *g*, *f*, *e*, *d*, *c*, *b*, Z, show the results of the calculation according to the rule, taking the same primitive strength for each piece.

1618. After what has been said in a preceding page, it is easy to conceive that the primitive unequal strengths would form an irregular polygon, whereof each point would answer to a different curve; whilst, supposing the same primitive strength to belong to each piece, there should be an agreement between the strengths and scantlings which constitute a regular curve.

1619. Thus it is to be observed that the points O and P of the regular polygon only vary from the regular curve, *m*, *l*, *k*, *i*, &c., because the ordinate LO is the product of a primitive strength diminished by the mean primitive strength which produced the ordinate of the curve KP. Hence the point P is above the properly correspondent point *k*.

1620. For the same reason, the point *c* is above its corresponding point X, because the relative ordinate C*c* is the product of a primitive strength greater than the mean which produced the point X.

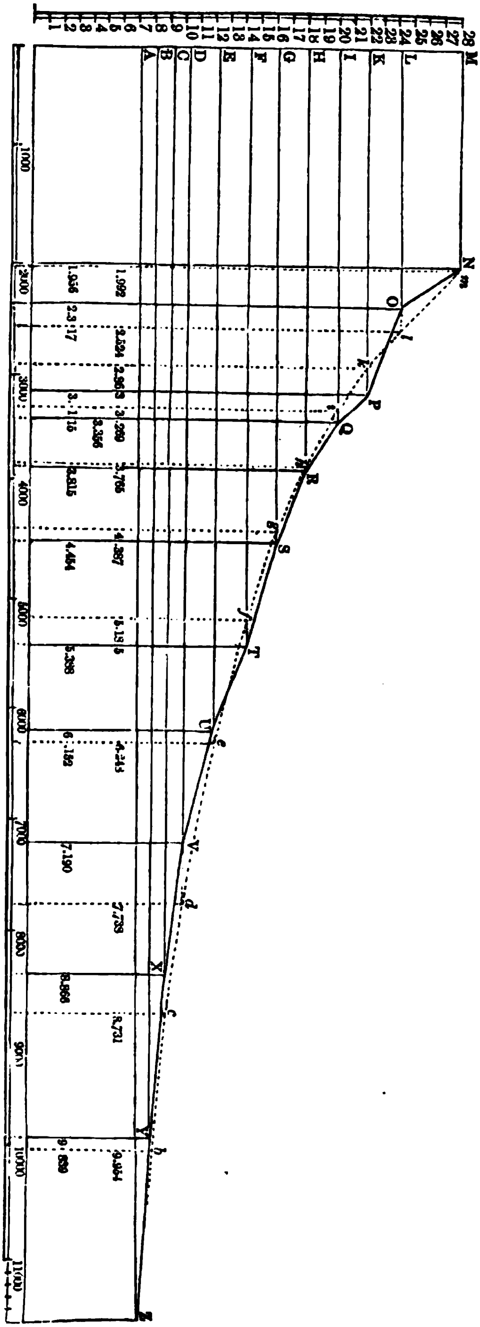

Fig. 612.

1621. Referring to the second table, we find that the primitive strength answering to the point O is but 60·76, and the value of the ordinate LO 2502, whilst that of the point P is 68·34, and the value of the ordinate KP 3364; and as the ordinates L*l* and K*k* corresponding to the curve are calculated upon the same primitive strength of 64·36, which for L*l* gives 2726, and for KP 3092: it follows that, in considering all these quantities as equal parts of a similar scale, the point P of the polygon should be (3364−3092=) 272 of these parts above the corresponding point *k* of the curve, and the point O 224 of those parts (2726−2502) below the point *l*.

1622. To render the researches made, available and useful, the table which follows has been calculated so as to exhibit the greatest strength of beams from pieces 3·198 in. square, up to 19·188 in. by 26·65 in.

The first column contains the length of each piece in English feet.

The second column, the proportion of the depth to the length; and

The third, the greatest strength of each piece in pounds averdupois.

The table is for oak; and it is to be recollected that the weight is supposed to be concentred in the middle of the bearing of the beams, and hence double what it would be if distributed over the whole length of each piece.

Experience, as well as investigation of the experiments, shows, that in order to resist all the efforts and strains which, in practice, timber has to encounter, the weight with which it is loaded ought to be very much less than its breaking weight, and that it ought not to be more than one tenth of what is given as the breaking weight in the following table, beyond which it would not be safe to trust it. The abstraction of the last figure on the right hand, therefore, gives the practicable strength by simple inspection. In a subsequent page, the reduction of the strength of oak to fir, which is in more general use in this country, will be introduced, so as to make the table of more general utility.

Table VI.

Showing the greatest Strength of Oak Timber lying horizontally, in pounds averdupois.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
3·198 inches (Eng.) square.			3·198 in. by 5·330 in.			4·264 inches square.		
1·599	6	12245	2·664	6	20418	2·842	8	16224
2·132	8	8747	3·553	8	15109	3·553	10	12728
2·664	10	7163	4·441	10	11934	4·264	12	10469
3·198	12	5889	5·330	12	9815	4·974	14	8696
3·730	14	4980	6·218	14	8303	5·685	16	7645
4·264	16	4290	7·106	16	7167	6·396	18	6702
4·796	18	3771	7·994	18	6283	7·106	20	5951
5·330	20	3247	8·883	20	5578	7·817	22	5333
5·862	22	3000	9·771	22	5010	8·528	24	4820
6·396	24	2711	10·660	24	4519	9·238	26	4386
6·928	26	2447	11·548	26	4111	9·949	28	4014
7·469	28	2257	12·436	28	3758	10·66	30	3686
7·994	30	2076	13·324	30	3459			
3·198 in. by 4·264 in.			3·198 in. by 6·396 in.			4·264 in. by 5·330 in.		
2·132	6	16326	3·198	6	24489	3·553	8	16224
2·842	8	12090	4·264	8	18136	4·441	10	12730
3·553	10	9547	5·330	10	14321	5·330	12	10469
4·264	12	7852	6·396	12	11778	6·218	14	8856
4·974	14	6642	7·462	14	9963	7·106	16	7645
5·685	16	5724	8·528	16	8761	7·994	18	6702
6·396	18	5027	9·594	18	7540	8·883	20	5951
7·106	20	4462	10·660	20	6694	9·771	22	5333
7·817	22	4000	11·726	22	6001	10·66	24	4820
8·528	24	3615	12·792	24	5422	11·55	26	4396
9·238	26	3289	13·858	26	4934	12·44	28	4013
9·949	28	3010	14·924	28	4514	13·32	30	3766
10·660	30	2767	15·990	30	4150			

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
4·264 in. by 6·396 in.			**5·330 in. by 6·396 in.**			**5·330 in. by 10·660 in.**		
4·264	8	20152	5·330	10	23869	8·883	10	39782
5·330	10	16913	6·396	12	19630	10·66	12	32717
6·396	12	13086	7·462	14	16374	12·44	14	27677
7·462	14	11071	8·528	16	14294	14·21	16	23888
8·528	16	9557	9·594	18	12568	15·99	18	20648
9·594	18	8379	10·66	20	11157	17·77	20	18595
10·66	20	7438	11·73	22	10001	19·54	22	16669
11·73	22	6668	12·79	24	9037	21·32	24	15063
12·79	24	6023	13·86	26	8223	23·10	26	13706
13·86	26	5482	14·92	28	7524	24·87	28	12551
14·92	28	5017	15·99	30	6918	26·65	30	11531
15·99	30	4613						
4·264 in. by 7·462 in.			**5·330 in. by 7·462 in.**			**6·396 inches square.**		
4·974	8	28224	6·218	10	27847	5·330	10	28643
6·218	10	22277	7·462	12	22901	6·396	12	23556
7·462	12	18321	8·705	14	18373	7·462	14	19927
8·705	14	15499	9·949	16	16724	8·528	16	17191
9·949	16	13379	11·19	18	14663	9·594	18	15082
11·19	18	11730	12·44	20	13017	10·66	20	13389
12·44	20	10413	13·68	22	11667	11·73	22	12001
13·68	22	9334	14·92	24	10544	12·79	24	10844
14·92	24	8427	16·17	26	9595	13·86	26	9857
16·17	26	7675	17·41	28	8778	14·92	28	8710
17·41	28	7022	18·65	30	8072	15·99	30	8302
18·65	30	6457						
4·264 in. by 8·528 in.			**5·330 in. by 8·528 in.**			**6·396 in. by 7·462 in.**		
5·685	8	22242	7·106	10	32225	5·218	10	33400
7·106	10	25460	8·528	12	26174	7·462	12	27482
8·528	12	21942	9·949	14	22141	8·705	14	23244
9·949	14	17713	11·37	16	19106	9·949	16	20067
11·37	16	15291	12·79	18	16757	11·19	18	17596
12·79	18	13410	14·21	20	14877	12·44	20	15321
14·21	20	11902	15·63	22	13338	13·68	22	13986
15·63	22	10677	17·06	24	12057	14·92	24	12652
17·06	24	9562	18·48	26	10965	16·17	26	11572
18·48	26	8772	19·90	28	10053	17·41	28	10534
19·90	28	8026	21·32	30	9225	18·65	30	9668
21·32	30	7480						
5·330 inches square.			**5·330 in. by 9·594 in.**			**6·396 in. by 8·528 in.**		
4·441	10	19890	7·994	10	35803	7·106	10	38158
5·330	12	16359	9·594	12	29445	8·528	12	31407
6·218	14	13839	11·19	14	24919	9·949	14	27341
7·106	16	11946	12·79	16	21493	11·37	16	22936
7·994	18	10473	14·39	18	18853	12·79	18	20110
8·863	20	9298	15·99	20	16737	14·21	20	17852
9·771	22	8334	17·59	22	15002	15·63	22	16001
10·66	24	7531	19·19	24	13556	17·06	24	14460
11·55	26	6863	20·78	26	12336	18·48	26	13158
12·44	28	6270	22·39	28	11287	19·90	28	12425
13·32	30	5765	23·98	30	10378	21·32	30	11070

6·396 in. by 9·594 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
7·994	10	42964
9·594	12	35334
11·19	14	29891
12·79	16	25791
14·39	18	22623
15·99	20	20084
17·59	22	18002
19·19	24	16267
20·79	26	14802
22·39	28	13544
23·98	30	12453

6·396 in. by 10·66 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
8·883	10	47738
10·66	12	39261
12·44	14	33212
14·21	16	28670
15·99	18	25135
17·77	20	22315
19·54	22	19978
21·32	24	18075
23·10	26	16447
24·87	28	15050
26·65	30	13638

6·396 in. by 11·726 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
9·771	10	52512
11·72	12	43176
13·68	14	36533
15·63	16	31537
17·59	18	27631
19·54	20	24546
21·50	22	22003
23·45	24	19883
25·41	26	18092
27·36	28	16554
29·31	30	15221

6·396 in. by 12·792 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
10·66	10	57285
12·79	12	47083
14·92	14	37854
17·06	16	34404
19·19	18	30164
21·32	20	26719
23·45	22	24003
25·58	24	21689
27·72	26	19377
29·85	28	18060
31·98	30	16000

7·462 inches square.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
6·218	10	35746
7·462	12	31911
8·705	14	27123
9·949	16	23413
11·19	18	20530
12·44	20	18224
13·68	22	16335
14·92	24	14761
16·17	26	13436
17·41	28	12637
18·65	30	10940

7·462 in. by 8·528 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
7·106	10	44577
8·528	12	36643
9·949	14	29806
11·37	16	26746
12·79	18	24060
14·21	20	21838
15·63	22	18667
17·06	24	16870
18·48	26	15418
19·90	28	14046
21·32	30	12915

7·462 in. by 9·594 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
7·994	10	50125
9·594	12	41221
11·19	14	35644
12·79	16	30108
14·39	18	26394
15·99	20	23432
17·59	22	21003
19·19	24	18979
20·79	26	17270
22·39	28	15802
23·98	30	14590

7·462 in. by 10·66 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
8·983	10	55738
10·66	12	45804
12·44	14	38757
14·21	16	33449
15·99	18	29226
17·77	20	26142
19·54	22	23325
21·32	24	21087
23·10	26	19139
24·97	28	17557
26·65	30	16144

7·462 in. by 11·726 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
9·771	10	60264
11·73	12	49384
13·68	14	42622
15·63	16	36792
17·59	18	31808
19·54	20	28637
21·50	22	24719
23·45	24	23196
25·40	26	21307
27·36	28	18928
29·31	30	17758

7·462 in. by 12·792 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
10·66	10	66832
12·79	12	55964
14·92	14	46497
17·06	16	40138
19·19	18	34992
21·32	20	31241
23·45	22	28003
25·58	24	25305
27·72	26	23068
29·85	28	21070
31·98	30	18373

7·462 in. by 13·858 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
12·61	10	72403
13·86	12	59546
16·17	14	50371
18·48	16	43483
19·72	18	38124

8·528 inches square.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
7·106	10	50921
8·528	12	41878
9·949	14	35426
11·37	16	30581
12·79	18	26812
14·21	20	23803
15·63	22	21342
17·06	24	19280
18·48	26	17345
19·90	28	16051
21·32	30	14760

8·528 in. by 9·594 in.

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
7·994	10	57285
9·594	12	47093
11·19	14	39854

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
12·79	16	34403
14·39	18	30170
15·99	20	26773
17·59	22	24003
19·19	24	21690
21·95	26	19737
23·45	28	17960
25·05	30	16605
8·528 in. by 10·66 in.		
8·883	10	62651
10·66	12	52348
12·44	14	44283
14·21	16	38227
15·99	18	33516
17·77	20	29754
19·54	22	26669
21·32	24	24100
23·10	26	21930
24·87	28	20066
26·65	30	18444
8·528 in. by 11·726 in.		
9·771	10	69975
11·73	12	57582
13·67	14	48711
15·63	16	42049
17·59	18	36668
19·54	20	32729
21·50	22	29337
23·45	24	26017
25·40	26	24124
27·36	28	22073
30·20	30	20295
8·528 in by 12·792 in.		
10·66	10	76381
12·79	12	62817
14·92	14	53139
17·06	16	45872
19·19	18	40219
21·32	20	35715
23·45	22	32004
25·58	24	28920
27·72	26	26356
29·85	28	24851
31·98	30	22149
8·528 in. by 13·858 in.		
11·55	10	82746
13·86	12	68052
16·17	14	57576
18·48	16	49627
20·79	18	43628

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
8·528 in. by 14·924 in.		
12·44	10	89111
14·92	12	73279
17·41	14	61996
19·90	16	53517
22·39	18	46923
9·594 inches square.		
7·994	10	64447
9·594	12	52992
11·19	14	45402
12·79	16	38704
14·39	18	33935
15·99	20	30125
17·59	22	27003
19·19	24	24401
20·79	26	22205
22·39	28	20317
23·98	30	18681
9·594 in. by 10·66 in.		
8·983	10	71607
10·66	12	58891
12·44	14	49818
14·21	16	43010
15·99	18	37705
17·77	20	33473
19·54	22	30003
21·32	24	27112
23·10	26	24671
24·87	28	22574
26·65	30	20756
9·594 in. by 11·726 in.		
9·771	10	78848
11·73	12	64780
13·68	14	54800
15·63	16	47305
17·59	18	41476
19·59	20	36820
21·50	22	33004
23·45	24	29825
25·40	26	27138
27·36	28	24830
29·21	30	22832
9·594 in. by 12·792 in.		
10·66	10	85929
12·79	12	70670
14·92	14	59782
17·06	16	51406
19·19	18	45247

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
21·32	20	40167
23·45	22	36004
25·58	24	32535
27·72	26	29606
29·85	28	27090
31·98	30	24908
9·594 in. by 13·858 in.		
11·55	10	93089
13·86	12	76458
16·17	14	64763
18·48	16	55906
20·79	18	49117
9·594 in. by 14·924 in.		
12·44	10	100250
14·92	12	82447
17·41	14	69745
19·90	16	60207
22·39	18	52771
10·66 inches square.		
8·883	10	79564
10·66	12	65435
12·44	14	55453
14·21	16	47783
15·99	18	41895
17·77	20	37192
19·54	22	33337
21·32	24	30125
23·10	26	27412
24·87	28	24083
26·65	30	23061
10·66 in. by 11·726 in.		
9·771	10	87520
11·73	12	71978
13·67	14	60889
15·63	16	52548
17·59	18	45985
19·54	20	40911
21·50	22	36671
23·45	24	33138
25·40	26	30155
27·36	28	27491
29·21	30	25369
10·66 in. by 12·792 in.		
10·66	10	95476
12·79	12	78521
14·92	14	66424
17·06	16	57340

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
19·19	18	50274
21·32	20	44631
23·45	22	40005
25·58	24	36151
27·72	26	32896
29·85	28	30100
31·98	30	27676
10·66 in. by 13·858 in.		
11·55	10	103633
13·86	12	85065
16·17	14	72037
18·48	16	62118
20·79	18	54463
10·66 in. by 14.924 in.		
12·44	10	111389
14·92	12	91609
17·41	14	77495
19·90	16	66896
22·39	18	58653
10·66 in. by 15·990 in.		
13·32	10	119345
15·99	12	98152
18·65	14	83030
21·32	16	71675
23·98	18	62841
11·726 inches square.		
9·771	10	96272
11·73	12	79174
13·67	14	66978
15·63	16	57818
17·59	18	51493
19·54	20	45002
21·50	22	40338
23·45	24	36407
25·40	26	33087
27·36	28	30350
29·21	30	27906
11·726 in. by 12·792 in.		
10·66	10	105023
12·79	12	86374
14·92	14	73067
17·06	16	63074
19·19	18	55301
21·32	20	49093
23·45	22	44006
25·58	24	38765

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
27·72	26	36185
29·85	28	33109
31·98	30	30443
11·726 in. by 13·858 in.		
11·55	10	113776
13·86	12	93572
16·17	14	79155
18·48	16	68328
20·79	18	60910
11·726 in. by 14·924 in.		
12·44	10	122528
14·92	12	100769
17·41	14	85244
19·90	16	73576
22·39	18	64518
11·726 in. by 15·99 in.		
13·32	10	131280
15·99	12	107968
18·65	14	91333
21·32	16	78842
23·98	18	69126
11·726 in. by 17·056 in.		
14·21	10	148784
17·06	12	122362
19·90	14	103511
22·74	16	89355
25·58	18	78344
11·72 in. by 18·122 in.		
15·10	10	157537
18·12	12	129561
21·14	14	109600
24·16	16	94611
27·18	18	82350
12·792 inches square.		
10·66	10	115572
12·79	12	89826
14·92	14	79709
17·06	16	68708
19·19	18	60329
21·32	20	53557
23·45	22	48006
25·58	24	43380
27·72	26	39475
29·85	28	36119
31·98	30	33211

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
12·792 in. by 13·858 in.		
11·55	10	124119
13·86	12	102078
16·17	14	86351
18·48	16	74542
20·79	18	65356
12·792 in. by 14·924 in.		
12·44	10	133667
14·92	12	110930
17·41	14	92994
19·90	16	80275
22·39	18	70384
12·792 in. by 15·99 in.		
13·32	10	143214
15·99	12	117783
18·65	14	99636
21·32	16	86010
23·98	18	75411
12·792 in. by 17·056 in.		
14·21	10	152762
17·06	12	125634
19·90	14	106279
22·74	16	91744
25·58	18	76238
12·792 in. by 18·122 in.		
15·10	10	162310
18·12	12	123487
21·14	14	112921
24·16	16	97479
27·18	18	85461
12·792 in. by 19·188 in.		
15·99	10	171857
19·19	12	141340
22·37	14	119565
25·58	16	103212
28·78	18	88894
12·792 in. by 20·254 in.		
16·88	10	181405
20·25	12	149191
23·63	14	126207
27·00	16	108946
29·38	18	95521

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
13·858 inches square.		
11·55	10	134463
13·86	12	110584
16·17	14	93547
18·48	16	80754
20·79	18	70802
13·858 in. by 14·924 in.		
12·44	10	144806
14·92	12	119092
17·41	14	100813
19·90	16	86966
22·39	18	76249
13·858 in. by 15·99 in.		
13·32	10	154825
15·99	12	127598
18·68	14	107939
21·32	16	93177
23·98	18	81755
13·858 in. by 17·056 in.		
14·21	10	164426
17·06	12	136153
19·90	14	114364
22·74	16	99396
25·58	18	91941
13·858 in. by 18·122 in.		
15·10	10	175836
18·12	12	144611
21·14	14	121332
24·16	16	105601
27·18	18	92588
13·858 in. by 19·188 in.		
15·99	10	141179
19·19	12	153115
22·37	14	129528
25·58	16	111813
28·78	18	98935
13·858 in. by 20·254 in.		
16·88	10	196522
20·25	12	161624
23·63	14	136724
27·00	16	118026
29·38	18	103481

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
13·858 in. by 21·326 in.		
17·77	10	205531
21·32	12	170130
24·87	14	144920
28·43	16	124237
31·98	18	108951
13·058 in. by 22·386 in.		
18·65	10	217210
22·38	12	178637
26·12	14	151115
29·85	16	130049
33·58	18	114374
14·924 inches square.		
12·44	10	155944
14·92	12	128092
17·41	14	108493
19·90	16	93655
22·39	18	82114
14·924 in. by 15·990 in.		
13·32	10	167083
15·99	12	137213
18·65	14	116242
21·32	16	100354
23·98	18	87980
14·924 in. by 17·056 in.		
14·21	10	178223
17·06	12	146674
19·90	14	123993
22·74	16	107034
25·58	18	93845
14·924 in. by 18·122 in.		
15·10	10	189362
18·12	12	155735
21·14	14	131741
24·16	16	113764
27·18	18	99711
14·924 in. by 19·188 in.		
15·99	10	200501
19·19	12	164895
22·37	14	139492
25·58	16	120415
28·78	18	105575

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
14·924 in. by 20·254 in.		
16·88	10	212547
20·25	12	174057
23·63	14	147331
27·00	16	127104
29·38	18	111441
14·924 in. by 21·326 in.		
17·77	10	212776
21·32	12	173218
24·87	14	150991
28·43	16	133733
31·98	18	117306
14·924 in. by 22·386 in.		
18·65	10	233917
22·38	12	192378
26·12	14	162737
29·85	16	140483
33·58	18	112372
14·924 in. by 23·452 in.		
19·54	10	246136
23·45	12	201540
27·36	14	170490
31·27	16	147173
35·18	18	129037
15·99 inches square.		
13·32	10	179009
15·99	12	147229
18·65	14	124547
21·32	16	107513
23·98	18	94164
15·99 in. by 17·056 in.		
14·21	10	190953
17·06	12	160244
19·90	14	132849
22·74	16	114680
25·58	18	100548
15·99 in. by 18·122 in.		
15·10	10	202888
18·12	12	166859
21·14	14	141153
24·16	16	121848
27·18	18	106832

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
15·99 in. by 19·188 in.			**17·056 in. by 18·122 in.**			**17·056 in. by 25·584 in.**		
15·99	10	214823	15·10	10	216412	21·32	10	305525
19·19	12	176584	18·12	12	177983	25·58	12	251360
22·37	14	149456	21·14	14	150563	29·85	14	212559
25·58	16	129015	24·16	16	129970	34·11	16	183421
28·78	18	113118	27·18	18	113954	38·37	18	160277
15·99 in. by 20·254 in.			**17·056 in. by 19·188 in.**			**18·122 inches square.**		
16·88	10	226757	15·99	10	229144	15·10	10	229907
20·25	12	186490	19·19	12	188456	18·12	12	187107
23·63	14	157759	22·37	14	158439	21·14	14	159973
27·00	16	136183	25·58	16	137617	24·16	16	142094
29·38	18	119401	28·78	18	120659	27·18	18	121077
15·99 in. by 21·326 in.			**17·056 in. by 20·254 in.**			**18·122 in. by 19·188 in.**		
17·77	10	238692	16·88	10	241875	15·99	10	243465
21·32	12	196365	20·25	12	197322	19·19	12	200131
24·87	14	166062	23·63	14	168276	22·37	14	169383
28·43	16	143350	27·00	16	145261	25·58	16	146217
31·98	18	125686	29·38	18	127341	28·78	18	128199
15·99 in. by 22·386 in.			**17·056 in. by 21·326 in.**			**18·122 in. by 20·254 in.**		
18·65	10	250626	17·77	10	254605	16·88	10	257091
22·38	12	206127	21·32	12	209391	20·25	12	211356
26·12	14	174365	24·87	14	177132	23·63	14	178793
29·85	16	150517	28·43	16	152807	27·10	16	154340
33·58	18	131770	31·98	18	134112	29·38	18	135261
15·99 in. by 23·452 in.			**17·056 in. by 22·386 in.**			**18·122 in. by 21·326 in.**		
19·54	10	262561	18·65	10	267334	17·77	10	270317
23·45	12	215935	22·38	12	219861	21·32	12	222479
27·36	14	182668	26·12	14	184989	24·87	14	188208
31·27	16	157685	29.85	16	160552	28·43	16	162463
35·18	18	138254	33·58	18	140768	31·98	18	142443
15·99 in. by 24·518 in.			**17·056 in. by 23·452 in.**			**18·122 in. by 22·386 in.**		
20·43	10	274495	19·54	10	280064	18·65	10	284043
24·52	12	225750	23·45	12	230330	22·38	12	233603
28·60	14	190751	27·36	14	190846	26·12	14	197611
32·69	16	164852	31·27	16	168772	29·85	16	170275
36·78	18	144538	35·18	18	147471	33·58	18	149566
17·056 inches square.			**17·056 in. by 24·518 in.**			**18·122 in. by 23·452 in.**		
14·21	10	203684	21·32	10	292795	19·54	10	297569
17·06	12	167513	25·58	12	240800	23·45	12	244727
19·90	14	141706	29 85	14	203702	27·36	14	207023
22·74	16	122967	34·11	16	175842	31·27	16	188710
25·58	18	107251	38·37	18	154174	35·18	18	156688

Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.	Length of each Piece in English Feet.	Proportion of Depth to Length.	Breaking Weight in lbs. averdupois.
18·122 in. by 24·518 in.			19·188 in. by 21·326 in.			19·188 in. by 25·584 in.		
20·43	10	310771	17·77	10	286430	31·32	10	343716
24·52	12	255851	21·32	12	235565	25·58	12	282679
28·60	14	216434	24·87	14	196074	29·85	14	140130
32·69	16	186833	28·43	16	171010	34·11	16	207092
36·78	18	163810	31·98	18	150823	38·37	18	180987
18·122 in. by 25·584 in.			19·188 in. by 22·386 in.			19·188 in. by 26·65 in.		
21·32	10	324621	18·65	10	300763	22·21	10	358037
25·58	12	256975	22·38	12	247344	26·65	12	294458
29·85	14	225844	26·12	14	209238	31·09	14	249092
34·11	16	194956	29·85	16	180621	35·53	16	216026
38·37	18	170933	33·58	18	158364	39·97	18	188529
19·188 inches square.			19·188 in. by 23·452 in.			20·254 inches square.		
15·99	10	257787	19·54	10	315073	16·88	10	287226
19·19	12	212107	23·45	12	259122	20·25	12	236220
22·37	14	179347	27·36	14	219101	23·63	14	199827
25·58	16	150818	31·27	16	189222	27 10	16	172498
28·78	18	135741	35·18	18	165905	29·38	18	151242
19·188 in. by 20·254 in.			19·188 in. by 24·518 in.			20·254 in. by 21·320 in.		
16·88	10	272108	20·43	10	329395	17·77	10	292343
20·25	12	223788	24·52	12	270901	21·32	12	248653
23·63	14	189310	28·60	14	229165	24·87	14	200345
27·00	16	163419	32·69	16	197824	28·43	16	181577
29·38	18	143281	36·78	18	173446	31·98	18	159202

1623. The table from which the above has been reduced to English measures, is extended to pieces of 31·980 in. square, and 47·97 ft. long; but as such scantlings rarely if ever occur in practice, unless strengthened by means of trussing, we have not considered it necessary to proceed beyond the scantling of 20·25 in. by 21·320 in., and 32 ft. long.

1624. Though the table is founded upon experiments on oak, it will serve for all sorts of wood, whose primitive strength is known, and the proportion they bear to oak. In order to facilitate calculations of that nature, the following table has been constructed, in which will be found the absolute and primitive strengths of the several sorts of timber, ordinarily used in carpentry, as also of some few others.

Table VII.

For applying the preceding Table to the Woods undermentioned. The primitive horizontal or transverse Strength of Oak is taken at 1000; its supporting or primitive vertical Strength at 807; and its cohesive or absolute Strength at 1821; being deduced from Pieces 19·188 lines English square.

Species of Wood.	Primitive horizontal Strength.	Primitive vertical Strength.	Absolute Strength.	Species of Wood.	Primitive horizontal Strength.	Primitive vertical Strength.	Absolute Strength.
Acacia (yellow)	780	1228	1560	Fir -	918	851	1250
Ash -	1072	1112	1800	Oak -	1000	807	1821
Beech - -	1032	986	2480	Pine-tree -	882	804	1141
Birch -	853	861	1980	Poplar -	586	680	940
Cedar -	627	720	1740	Service-tree	965	981	1642
Cherry tree -	961	986	1912	Sycamore -	900	968	1564
Chestnut -	957	950	1944	Yew-tree -	1037	1375	2287
Elm -	1077	1075	1980	Walnut -	900	753	1120

Method of using the above Table for horizontal Timbers.

1625. To find the strength of a beam of fir 23·98 ft. long and 5·330 by 9·594 in. Against these dimensions in the Table VI. we find 10378 as the breaking weight. In the Table VII. we find the primitive horizontal strength of oak is to that of fir as 1000 to 918. Hence 1000 : 918 : : 10378 to a fourth term which $=9527$; which expresses the greatest strength of such a beam of fir, or that which would break it. Cutting off the last figure on the right hand, that is, taking one tenth, we have 952 for the greatest weight with which such a beam should be loaded.

1626. If the beam be of chesnut, whose primitive strength is 957, the proportion becomes 1000 : 957 : : 10378 : 9931 = the greatest strength of such a piece, and $\frac{9931}{10}$ the greatest weight with which it should be loaded.

Method of Application for the vertical bearing Strength.

1627. To find the vertical strength of an oak post 9·594 in. square, and 9·594 ft. high, we shall find in Table VII. for the primitive vertical strength, 807 for 19·188 lines English superficial. But as this strength diminishes as the relative height of the post increases, which in this case is 12 times, we must (1601.), take only $\frac{5}{6}$ of 807, according to the progression there given, that is, 672½.

1628. The post being 9·594 in. square, its area will be $\overline{9{\cdot}594\times12}|^2=13254{\cdot}756$, and $\frac{13254{\cdot}756}{19{\cdot}188}=692{\cdot}34$, and $692{\cdot}34\times672{\cdot}5=465000$, which divided by $10=46500$; is the weight with which without risk the post may be loaded.

1629. If the post be of fir, whose primitive vertical strength to that of oak is as 851 to 807, we have only to use the proportion 807 : 465000 : : 851 : 490980, which divided by $10=49098$; the greatest weight with which it should be loaded.

Method for obtaining the absolute or cohesive Strength.

1630. In respect of this species of strength, which is that with which timber resists being drawn asunder in the direction of its fibres by weights acting at its ends, it is only necessary to multiply the area of the section of the piece reduced to lines by the tabular number 1821. if it be oak, and divide the product by 19·188, and the quotient will show the greatest effort it can bear.

1631. Thus for a piece of oak 9·594 in. square, we have $\frac{13254{\cdot}75\times1821}{19{\cdot}188}=1260700$ (in round numbers), which divided by 10 gives the greatest weight that should be suspended to the piece.

1632. From Table VII. it will be seen that in the direction of the absolute strength, beech is the strongest wood, and that strength will be $\frac{13254{\cdot}75\times2480\text{ (the tabular number)}}{19{\cdot}188}=1363850$, which will give 136385 for the greatest weight to be attached.

Of the Strength of Timbers in an inclined Position.

1633. If we suppose the vertical piece AB to become inclined to the base, experiment proves that its strength to resist (*fig.* 614.) a vertical effort diminishes as its inclination increases; so that, if from the upper part in D a vertical D*f* be let fall, and from the points of the base the horizontal line BC be drawn, the strength of the piece diminishes as B*f* increases: whence, I. The strength of a vertical piece is to that of an inclined piece of the same length and scantling as the length AB is to B*f*, or as the radius is to the sine of the inclination of the piece. II. Vertical pieces have the greatest strength to resist a weight, and the weakest are pieces which lie horizontally.

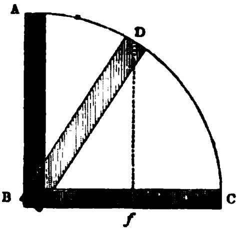

Fig. 614.

1634. The first of these results furnishes an easy method of finding, by the aid of the last table, the strength of a piece of timber whose length and inclination are known. Thus, suppose a piece of oak inclined 4·692 feet and 9·594 feet long; its size being 8·528 by 9·594 inches, whose area, therefore, is 11781·74 lines. This must be divided by the tabular number 19·188, and the quotient will be 614. In table VII., 807 is the primitive vertical strength of oak for 19·188 lines superficial of section; but as the piece is more than 12 times the width of its base, we are, as before observed, to take only $\frac{5}{6}$ of 807, or 672·5, which is to be multiplied by 614, and the product is 412915. Then the proportion 9·594 : 4·692 : : 412915 : 843400 is the strength, which, divided by $10=84340$, is the greatest load to which the inclined piece ought to be subjected.

1635. In a section of a following chapter, that on Practical or Constructive Carpentry, tables of scantlings for timbers will be given, more immediately useful to the practical architect than those deducible from the above rules.

CHAP. II.

MATERIALS USED IN BUILDING.

SECT. I.

STONE.

1636. IT is not our intention to advert to the stone which the Continent affords for building purposes; a knowledge of the different kinds there found would be of no use to the English architect, and would occupy too much of our space as mere information. It is almost superfluous to say that the choice of stone for a building intended to be durable is of the very highest importance. "In modern Europe," it has been observed, "and particularly in Great Britain, there is scarcely a public building, of recent date, which will be in existence a thousand years hence. Many of the most splendid works of modern architecture are hastening to decay in what may be justly called the infancy of their existence, if compared with the date of public buildings that remain in Italy, in Greece, in Egypt, and the East."

1637. The various sorts of stone take their names either from the places where they are quarried or from the substances which principally enter into their composition. The term "Freestone," which is used in a very arbitrary way, is, as its name implies, that sort which can be wrought with the mallet and chisel, or cut with the saw, an operation which cannot be performed upon granite, whose hardness requires it to be dressed with pointed tools of different weights and sizes. It includes the two great general divisions of Limestone and Sandstone. The limestone of Portland is that which has for many years past been chiefly used in the metropolis. Latterly, other sorts have found their way in from the provinces; and though, from many circumstances, we do not think it likely that Portland stone, from its facility of transport and other causes, will be altogether superseded, there is no doubt that its use is on the wane from the introduction of provincial sorts.

1638. We shall proceed, after some preliminary observations, to give, from the Report lately addressed to the Commissioners of Woods and Forests, on the occasion of selecting the stone for building the new Houses of Parliament, a view of the principal sorts of stone found and used in the island.

1639. The qualities requisite for a building stone are hardness, tenacity, and compactness. It is not the hardest stone which has always the greatest tenacity or toughness; for limestone, though much softer, is not so easily broken as glass.

1640. The decay and destruction of stone are accelerated by nearly the same causes as those which destroy rocks themselves on the surface of the globe. Such causes are of two kinds: those of decomposition and those of disintegration. The former effects a chemical change in the stone itself, the latter a mechanical division and separation of the parts. The effects of the chemical and mechanical causes of the decomposition of stone in buildings are much modified, according to their situation, as, in the town or country. In populous and smoky towns the state of the atmosphere accelerates decomposition more than in those placed in the open country.

1641. "As regards the sandstones that are usually employed for building purposes, and which are generally composed of either quartz or siliceous grains, cemented by siliceous, argillaceous, calcareous or other matter, their decomposition is effected according to the nature of the cementing substance, the grains being comparatively indestructible. With respect to limestones composed of carbonate of lime, or the carbonates of lime and magnesia, either nearly pure or mixed with variable proportions of foreign matter, their decomposition depends, under similar circumstances, upon the mode in which their component parts are aggregated, those which are most crystalline being found to be the most durable, while those which partake least of that character suffer most from exposure to atmospheric influences.

1642. "The varieties of limestones termed Oolites (or Roestones) being composed of oviform bodies cemented by calcareous matter of a varied character, will of necessity suffer unequal decomposition, unless such oviform bodies and the cement be equally coherent and of the same chemical composition. The limestones which are usually termed '*shelly*,' from being chiefly formed of either broken or perfect fossil shells cemented by calcareous matter, suffer decomposition in an unequal manner, in consequence of the shells, which, being for the most part crystalline, offer the greatest amount of resistance to the decomposing effects of the atmosphere.

1643. "Sandstones, from the mode of their formations, are very frequently laminated, more especially when micaceous, the plates of mica being generally deposited in planes parallel to their beds. Hence, if such stone be placed in buildings with the planes of lamination in a vertical position, it will decompose in flakes, according to the thickness of the laminæ; whereas, if it be placed so that the planes of lamination be horizontal, that is, most commonly upon its natural bed, the amount of decomposition will be comparatively immaterial.

1644. "Limestones, such at least as are usually employed for building purposes, are not liable to the kind of lamination observable in sandstones; nevertheless, varieties exist, especially those commonly termed *shelly*, which have a coarse laminated structure, generally parallel to the planes of their beds, and therefore the same precaution in placing such stone in buildings so that the planes of lamination be horizontal, is as necessary as with the sandstones above noticed.

1645. "The chemical action of the atmosphere produces a change in the entire matter of the limestones, and in the cementing substance of the sandstones according to the amount of surface exposed to it. The mechanical action due to atmospheric causes occasions either a removal or a disruption of the exposed particles, the former by means of powerful winds and driving rains, and the latter by the congelation of water forced into or absorbed by the external portions of the stone. These effects are reciprocal, chemical action rendering the stone liable to be more easily affected by mechanical action, which latter, by constantly presenting new surfaces, accelerates the disintegrating effects of the former.

1646. "Buildings in this climate are generally found to suffer the greatest amount of decomposition on their southern, south-western, and western fronts, arising doubtless from the prevalence of winds and rains from those quarters; hence it is desirable that stones of great durability should at least be employed in fronts with such aspects.

1647. "Buildings situated in the country appear to possess a great advantage over those in populous and smoky towns, owing to lichens, with which they almost invariably become covered in such situations, and which, when firmly established over their entire surface, seem to exercise a protective influence against the ordinary causes of the decomposition of the stone upon which they grow.

1648. "As an instance of the difference in degree of durability in the same material subjected to the effects of the atmosphere in town and country, we may notice the several frusta of columns and other blocks of stone that were quarried at the time of the erection of St. Paul's Cathedral in London, and which are now lying in the island of Portland, near the quarries from whence they were obtained. These blocks are invariably found to be covered with lichens, and although they have been exposed to all the vicissitudes of a marine atmosphere for more than 150 years, they still exhibit, beneath the lichens, their original forms, even to the marks of the chisel employed upon them, whilst the stone which was taken from the same quarries (selected, no doubt, with equal, if not greater, care than the blocks alluded to) and placed in the cathedral itself, is, in those parts which are exposed to the south and south-west winds, found in some instances to be fast mouldering away. Colour is of more importance in the selection of a stone for a building to be situated in a populous and smoky town, than for one to be placed in an open country, where all edifices usually become covered, as before stated, with lichens; for although in such towns those fronts which are not exposed to the prevailing winds and rains will soon become blackened*, the remainder of the building will constantly exhibit a tint depending upon the natural colour of the material employed.

1649. "Before we proceed to adduce a few examples of the present condition of the various buildings we have examined, we would wish to observe that those which are highly decorated, such as the churches of the Norman and pointed styles of architecture, afford a more severe test of the durability of any given stone, all other circumstances being equal, than the more simple and less decorated buildings, such as the castles of the fourteenth and fifteenth centuries, inasmuch as the material employed in the former class of buildings is worked into more disadvantageous forms than in the latter, as regards exposure to the effects of the weather; and we would further observe, that buildings in a state of ruin, from being deprived of their ordinary protection of roofing, glazing of windows, &c., constitute an equally severe test of the durability of the stone employed in them.

1650. "As examples of the degree of durability of various building stones in particular localities, the following may be enumerated. Of the sandstone buildings which we examined, we may notice the remains of Ecclestone Abbey, of the thirteenth century, near Barnard Castle, constructed of a stone closely resembling that of the Stenton quarry in the vicinity, as exhibiting the mouldings and other decorations, even to the dog's-tooth ornament, in excellent condition. The circular keep of Barnard, apparently also built of the same material, is in fine preservation. Tintern Abbey may also be noticed as a sandstone edifice that has to a considerable extent resisted decomposition; for although it is decayed in some parts, it is nearly perfect in others. Some portions of Whitby Abbey are likewise in a perfect state, whilst others are fast yielding to the effects of the atmosphere. The older portions of Ripon Cathedral, constructed of sandstone, are in a fair state of preservation. Rivaulx Abbey is another good example of an ancient sandstone building in a fair condition. The Norman keep of Richmond Castle in Yorkshire affords an instance of a moderately hard sandstone which has well resisted decomposition.

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* We must take leave to question this statement; as, for instance, in St. Paul's Cathedral we find the northern front peculiarly black, whilst the south front and south-western angle are comparatively white. This we have always considered to have arisen from the more constant action of the sun's rays upon them.

1651. "As examples of sandstone buildings of more recent date in a good state of preservation, we may mention Hardwicke Hall, Haddon Hall, and all the buildings of Craigleith Stone in Edinburgh and its vicinity. Of sandstone edifices in an advanced state of decomposition we may enumerate Durham Cathedral, the churches at Newcastle upon Tyne, Carlisle Cathedral, Kirkstall Abbey, and Fountains Abbey. The sandstone churches of Derby are also extremely decomposed; and the church of St. Peter at Shaftesbury is in such a state of decay that some portions of the building are only prevented from falling by means of iron ties.

1652. "As an example of an edifice constructed of a calciferous variety of sandstone, we may notice Tisbury Church, which is in unequal condition, the mouldings and other enrichments being in a perfect state, whilst the ashler, apparently selected with less care, is fast mouldering away.

1653. "The choir of Southwell Church, of the twelfth century, may be mentioned as affording an instance of the durability of a magnesio-calciferous sandstone, resembling that of Mansfield, after long exposure to the influences of the atmosphere.

1654. "Of buildings constructed of magnesian limestone we may mention the Norman portions of Southwell Church, built of stone similar to that of Bolsover Moor, and which are throughout in a perfect state, the mouldings and carved enrichments being as sharp as when first executed. The keep of Koningsburgh Castle, built of a magnesian limestone from the vicinity, is also in a perfect state, although the joints of the masonry are open in consequence of the decomposition and disappearance of the mortar formerly within them. The church at Hemmingborough, of the fifteenth century, constructed of a material resembling the stone from Huddlestone, does not exhibit any appearance of decay. Tickhill Church, of the fifteenth century, built of a similar material, is in a fair state of preservation. Huddlestone Hall, of the sixteenth century, constructed of the stone of the immediate vicinity, is also in good condition. Roche Abbey, of the thirteenth century, in which stone from the immediate neighbourhood has been employed, exhibits generally a fair state of preservation, although some portions have yielded to the effects of the atmosphere.

1655. "As examples of magnesian limestone buildings in a more advanced state of decay, we may notice the churches at York, and a large portion of the Minster, Howden Church, Doncaster Old Church, and others in that part of the country, many of which are so much decomposed that the mouldings, carvings, and other architectural decorations are often entirely effaced.

1656. "We may here remark, that, as far as our observations extend, in proportion as the stone employed in magnesian limestone buildings is crystalline, so does it appear to have resisted the decomposing effects of the atmosphere; a conclusion in accordance with the opinion of Professor Daniell, who has stated to us that from the results of experiments, he is of opinion 'the nearer the magnesian limestones approach to equivalent proportions of carbonate of lime and carbonate of magnesia, the more crystalline and better they are in every respect.'

1657. "Of buildings constructed of oolitic and other limestones, we may notice the church of Byland Abbey, of the twelfth century, especially the west front, built of stone from the immediate vicinity, as being in an almost perfect state of preservation. Sandysfoot Castle, near Weymouth, constructed of Portland oolite in the time of Henry VIII., is an example of that material in excellent condition; a few decomposed stones used in the interior (and which are exceptions to this fact) being from another oolite in the immediate vicinity of the castle. Bow and Arrow Castle, and the neighbouring ruins of a church of the fourteenth century, in the Island of Portland, also afford instances of the Portland oolite in perfect condition. The new church in the island, built in 1766, of the variety of the Portland stone termed *roach*, is in an excellent state throughout, even to the preservation of the marks of the chisel.

1658. "Many buildings constructed of a material similar to the oolite of Ancaster, such as Newark and Grantham Churches, and other edifices in various parts of Lincolnshire, have scarcely yielded to the effects of atmospheric influences. Windrush Church, built of an oolite from the neighbouring quarry, is in excellent condition, whilst the Abbey Church of Bath, constructed of the oolite in the vicinity of that city, has suffered much from decomposition; as is also the case with the cathedral, and the churches of St. Nicholas and St. Michael in Gloucester, erected of a stone from the oolitic rocks of the neighbourhood.

1659. "The churches of Stamford, Ketton, Colley Weston, Kettering, and other places in that part of the country, attest the durability of the Shelley oolite, termed *Barnack Rag*, with the exception of those portions of some of them for which the stone has been ill-selected. The excellent condition of those parts which remain of Glastonbury Abbey show the value of a shelly limestone similar to that of Doulting, whilst the stone employed in Wells Cathedral, apparently of the same kind, and not selected with equal care, is in parts decomposed. The mansion, the church, and the remains of the abbey at Montacute, as also many other buildings in that vicinity, constructed of the limestone of Ham Hill, are in excellent condition. In Salisbury Cathedral, built of stone from Chilmark, we have evidence of the general durability of a siliciferous limestone; for, although the west front has somewhat yielded to the effects of the atmosphere, the excellent condition of the building generally is most striking.

1660. " In the public buildings of Oxford, we have a marked instance both of decomposition and durability in the materials employed; for whilst a shelly oolite, similar to that of Taynton, which is employed in the more ancient parts of the cathedral, in Merton College Chapel, &c., and commonly for the plinths, string-courses, and exposed portions of the other edifices in that city, is generally in a good state of preservation, a calcareous stone from Heddington, employed in nearly the whole of the colleges, churches, and other public buildings, is in such a deplorable state of decay, as in some instances to have caused all traces of architectural decoration to disappear, and the ashler itself to be in many places deeply disintegrated.

1661. " In Spofforth Castle we have a striking example of the unequal decomposition of two materials, a magnesian limestone and a sandstone; the former employed in the decorated parts, and the latter for the ashler or plain facing of the walls. Although the magnesian limestone has been equally exposed with the sandstone to the decomposing effects of the atmosphere, it has remained as perfect in form as when first employed, while the sandstone has suffered considerably from the effects of decomposition.

1662. " In Chepstow Castle, a magnesian limestone in fine preservation, and a red sandstone in an advanced state of decomposition, may be observed, both having been exposed to the same conditions as parts of the same archways; and in Bristol Cathedral there is a curious instance of the effects arising from the intermixture of very different materials, a yellow limestone and a red sandstone, which have been indiscriminately employed both for the plain and decorated parts of the building; not only is the appearance in this case unsightly, but the architectural effect of the edifice is also much impaired by the unequal decomposition of the two materials, the limestone having suffered much less from decay than the sandstone.

1663. " Judging, therefore, from the evidence afforded by buildings of various dates, there would appear to be many varieties of sandstone and limestone employed for building purposes which successfully resist the destructive effects of atmospheric influences; amongst these the sandstones of Stenton, Whitby, Tintern, Rivaulx, and Cragleith, the magnesio-calciferous sandstones of Mansfield, the calciferous sandstone of Tisbury, the crystalline magnesian limestones, or *Dolomites* of Bolsover, Huddlestone and Roche Abbey, the oolites of Byland, Portland, and Ancaster, the Shelly oolites and limestones of Barnack and Ham Hill, and the siliciferous limestone of Chilmark appear to be amongst the most durable. To these, which may all be considered as desirable building materials, we are inclined to add the sandstones of Darley Dale, Humbie, Longannet, and Crowbank, the magnesian limestones of Robin Hood's Well, and the oolite of Ketton, although some of them may not have the evidence of ancient buildings in their favour." The Report upon which we have drawn so largely, and from which we shall extract still larger drafts, then proceeds to close by a preference to limestones on account "of their more general uniformity of tint, their comparatively homogeneous structure, and the facility and economy of their conversion to building purposes," of which it prefers the crystalline; on which account, and its combination with a close approach to the equivalent proportions of carbonate of lime and carbonate of magnesia, for uniformity in structure, facility and economy in conversion, and for advantage of colour, the parties to the Report prefer the magnesian limestone or dolomite of Bolsover Moor and its neighbourhood. The Report deserves every commendation. There are points which, were we disposed to cavil, might furnish matter for it, but upon the whole it has been well done, and is the first scientific step the government of this country has ever taken in respect of practical architecture.

1664. The following table presents a synoptical, and, to the architect, important view of the relative value, in every respect, of the principal species of stone which the various provinces of England afford for building purposes, and is condensed from the Report so much at length above quoted.

SANDSTONES.

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State. lb. oz.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London. s. d.	Where used.
ABERCARNE and NEWBRIDGE, near Newport, Monmouthshire	Sir B. Hall, Bart.	Quartz and siliceous grains, moderately fine, with argillo-siliceous cement; micaceous, and with remains of fossil plants	Dark bluish grey.	167 15	1 to 10 tons, in thicknesses of 5 feet.	4¾d., or 5s. per ton	1 5	Old churches and modern buildings in vicinity; new Docks at Newport and Cardiff.
BALL CROSS	- -	Siliceous grains with argillo-siliceous cement; occasionally micaceous, ferruginous.	Ferruginous brown striped, and zoned in deeper tints.	- -	- -	- -	- -	At Chatsworth and Bakewell.
BARBADOES, Tintern, Monmouthshire.	Duke of Beaufort.	Fine and coarse quartz, and other siliceous grains, with argillo-siliceous cement, ferruginous spots, and plates of mica.	Light greyish brown.	146 12	1 to 10 tons, thickest bed 10 to 12 ft.	10d. to 1s.	- -	Tintern Abbey.
BINNIE, Uphall, and in Linlithgowshire.	Earl of Buchanan.	Fine quartz grains, with argillo-siliceous cement, micaceous, chiefly in planes of beds.	Brownish grey.	140 1	Bands 14 to 18 ft. thick (3 in number).	1s. 1d. to 2s. for largest blocks.	2 9 to 3 8	New club-house in Prince's Street, Edinburgh, and numerous private houses there and in Glasgow.
BOLTON'S QUARRY, Aislaby, Yorkshire.	Messrs. Elgie and Lawson, as executors of the late Mr. Noble, of York.	Moderately fine siliceous grains, with argillo-siliceous cement, plates of mica, and spots of carbon disseminated.	Warm light brown.	126 11	100 ft. cube; top beds for house building, bottom beds for docks. Beds 3 to 8 ft. thick.	10d. to 1s.	1 9 to 2 1	Whitby Abbey, New University Library at Cambridge, Scarborough and Bridlington Piers, Sheerness and St. Katharine's Docks, &c.
BRAMLEY FALL (Old Quarry), near Leeds, Yorkshire.	Earl of Cardigan.	Quartz grains (often coarse), and decomposed felspar, with argillo-siliceous cement. Mica rare. Small ferruginous spots disseminated.	Light ferruginous brown.	142 3	Up to 18 tons.	- -	- -	In numerous bridges, waterworks, &c.
CALVERLEY, Tunbridge Wells, Kent.	John Ward, Esq., Holwood Park, Bromley, Kent.	Fine siliceous grains, with a slightly calcareous cement.	Variegated browns.	118 1	70 or 80 ft., and upwards to 500. Beds to 3½ ft.	4d. to 6d.	1 2 to 1 4	Upper part of new church at Tunbridge Wells; Catholic Chapel, the Calverley Hotel, new Market House, and Victoria National School, and about 100 houses, &c., at Tunbridge Wells and its vicinity.

SANDSTONES — *continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.			*s. d.*	
Craigleith, Craigleith Hill, near Edinburgh.	W. R. Ramsay, Esq., of Barnton.	Fine quartz grains, with a siliceous cement, slightly calcareous, occasional plates of mica.	Whitish grey.	145 14	Any practicable length and breadth, from 6 in. to 10 ft. thick.	9*d.* to 2*s.* 6*d.*, according to quality.	1 10½ to 3 7½	Used extensively in public buildings in Edinburgh; the College (1580), Registry (1774), courts of law, Custom House, Royal Exchange, National Monument, and numerous churches, and now using for repairs at Blackfriars Bridge.
Crawbank, Borrowstones, Linlithgowshire.	Duke of Hamilton.	Fine quartzose grains, with an argillo-siliceous cement, somewhat ferruginous; disseminated mica.	Light ferruginous brown.	129 2	5 ft. thick, 6 ft. broad; 10 ft. long.	1*s.* for blocks of not more than 5 cubic ft.	2 2	A Roman bridge (A. D. 140.), old church of Kinneil, of the twelfth century.
Duffield Bank, Duffield, Derbyshire.	Mrs. Strathan.	Quartz grains of moderate size, and decomposed felspar, with an argillo-siliceous cement, ferruginous spots, and occasionally plates of mica.	Light brown with dark brown and purplish tints.	132 14	150 ft.; thickest beds about 4 ft.; half the depth brown, half white.	1*s.* 1*d.* the white stone, 9*d.* the brown stone.	- -	St. Mary's Bridge, Reporter Office, Mechanics' Lecture Hall, and Bishop Ryder's Church now building (Derby); also Duffield Bridge and chimney shafts to Grammar School, Birmingham.
Duke's Quarries, Holt Stanwell Bridge, Derbyshire.	Duke of Devonshire.	Quartz grains, generally coarse, with decomposed felspar, and an argillo-siliceous cement; ferruginous spots.	Red, varied with green, brown, and grey.	144 8	- -	7*d.*	2 8	Penitentiary at Millbank, and the filling in parts of Waterloo Bridge, London.
Elland Edge, near Halifax, Yorkshire.	- -	Fine quartz grains, with an argillo-siliceous cement, micaceous in planes of beds.	Light grey brown.	153 4				
Gatherley Moor, near Richmond, Yorkshire.	John Warton, Esq. Gisborough.	Quartz grains of moderate size, and an argillo-siliceous cement; ferruginous spots and plates of mica.	Cream.	135 13	1 to 3 tons, a bed 12 ft. deep.	8*d.* for the 12 ft. bed.	2 1	Aste Hall near Richmond, and Caterick bridges over the Swale; Purse Bridge over the Tees; Skelton Castle, Darlington Town Hall, Lockburn Hall, and numerous modern buildings.

SANDSTONES — *continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s. d.*	*s. d.*	
GATTON, Gatton, Surrey.	Lord Monson.	Fine siliceous grains, with a calcareo-siliceous cement, containing green silicate of iron and plates of mica.	Greenish light brown.	108 1	35 to 60 ft. cube, from 4 to 10 ft. long.	1 4 to 1 6	- -	Hampton Court and Windsor Castle, &c.; many churches in Surrey; Town Hall and Almshouse Establishment at Croydon; and several modern buildings in the parish of Gatton.
GLAMMIS, Forfarshire.	Earl of Strathmore's trustees.	Siliceous grains of moderate size; cement slightly calcareous; mica abundant in planes of beds.	Purple grey.	161 2	Any practicable size; thickest bed 6 ft.	0 7 to 1 0	about 19*s.* per ton.	Glammis Castle and Inverquharity Castle, supposed of the tenth century; Cortachy Castle; and in modern buildings; Lendertis House, &c.
HEDDON, near Newcastle, Northumberland.	Mrs. Bewick, near Newcastle upon Tyne.	Coarse quartz grains, and decomposed felspar, with an argillo-siliceous cement, ferruginous spots.	Light brown ochre.	130 11	Beds 4 to 12 ft. thick.	0 6 to 0 10	1 8 to 2 0	Church at Heddon, steeple, 1764; Norman chancel; columns of portico to theatre, and Grey Monument at Newcastle; and nearly all the buildings, ancient and modern, in and about Newcastle.
HOLLINGTON, Staffordshire.	Sir J. Gibbons, Bart.,near Staines, Middlesex.	Quartz grains of moderate size, with an argillo-siliceous cement; plates of mica.	Light brownish grey.	133 1	30 to 40 ft. square, and 8 ft. thick.	0 7 to 1 0	2 6	Trentham Hall, Drayton Manor, Heathhouse, and various public and private buildings in Staffordshire; Town Hall, Derby; Mear Hall, Cheshire, &c.
HUMBIE, Humbie, Linlithgowshire.	Earl of Hopetoun.	Fine quartz grains, with siliceous cement; slightly calcareous; mica chiefly in planes of beds.	Pale grey and light brown.	White 140 3 grey 135 13	90 cubic ft. and upwards, if required; thickest bed 8 ft.	1 0 to 1 10	2 6 to 3 2	Newliston House, Kirkliston; Dundas Castle; additions to the Royal Institution; front of Surgeons' Hall, spire of Tron Church, and various other public buildings in Edinburgh; also in Glasgow.
LONGANNET, near Kincardine, in Perthshire.	Trustees of late Lord Keith.	Fine quartz grains, with siliceous cement, containing oxide of iron; a few plates of mica.	Light ferruginous brown.	131 11	4 to 5 tons; thickest beds 5 ft.	0 8 to 2 6	1 8 to 3 6	Staadt House, Amsterdam; Exchange, Edinburgh; Tulle Mare Castle, Perthshire; and part of a street in Perth.

SANDSTONES — *continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		s. d.	s. d.	
Munlochy, in Ross-shire.	John Matheson, Esq., of Bennetsfield.	Fine siliceous grains, with an argillo-siliceous cement; micaceous.	Red and variegated.	160 9	Of large size; beds 2½ to 6 ft. thick.	0 5 to 0 5½	- -	Cathedral Church of Ross at Fortrose, A.D. 1124; Inverness Old Bridge, Cromwell Court, &c.
Mylnefield, or **Ringoodie**, near Dundee, in Perthshire.	James Mylne, Esq.	Fine siliceous grains, with a calcareo-argillo-siliceous cement; micaceous in planes of beds.	Purplish grey.	160 0	Any practicable size.	0 9 to 1 5	- -	Old steeple of Dundee, 12th century, well preserved; Royal Asylum of Dundee, &c.; Bell Rock Lighthouse, Royal Asylum of Perth, Kinfauns Castle, Castle Huntley, &c. &c.
Park Spring, near Leeds, Yorkshire.	Earl of Cardigan.	Fine quartz grains, and decomposed felspar, with an argillo-siliceous cement; mica chiefly in planes of beds.	Light ferruginous brown.	151 1	10 to 12 ft. long: thickest bed 2 ft. 4 in.	0 7	2 1½ to 2 5	Commercial buildings at Leeds, from the old quarry, which is of exactly similar stone to that of this quarry.
Pensher, near Houghton-le-Spring, Durham.	Marquess of Londonderry.	Coarse quartz grains, with an argillo-siliceous cement; plates of mica.	Pale whitish brown.	134 5	Any practicable size; thickest bed 20 ft.	0 8¾	1 7	Pensher Chapel; Scotch Church, Sunderland; Sunderland Pier, Seaham Harbour, Victoria Bridge, on the Wear, &c.
Pyotdykes, near Dundee, Forfarshire.	Alexander Clayhills, Esq., Innergowrie.	Siliceous grains of moderate size, with a calcareo-argillo-siliceous cement; micaceous.	Purplish grey.	162 8	Thickest bed 3 to 4 ft.	0 10 to 1 2	2 1 to 2 5	Extensively for the works at Dundee Harbour, &c.
Scotgate Head, Huddersfield, Yorkshire.	The freeholders of Onley.	Quartz grains, of moderate size, with an argillo-siliceous cement; mica in planes of beds, and occasional specks of carbon.	Light greenish grey.	158 0	Thickest bed 3 ft. 6 in.	0 8	1 2	York Castle; Bath Hotel, at Huddersfield.
Stancliff, or **Darley Dale**, near Bakewell, Derbyshire.	A. H. Heathcote, Esq., Blackwell.	Quartz grains of moderate size, and decomposed felspar, with an argillo-siliceous cement, ferruginous spots, and plates of mica.	Light ferruginous brown.	148 3	Of very large size.	1 5	3 3	Abbey in Darley Dale; Stancliff Hall, Birmingham; Grammar School, Birmingham; and Nottingham Railway Station Houses.
Stenton, near Barnard Castle, Durham.	Duke of Cleveland.	Fine quartz grains, and decomposed felspar, with an argillo-siliceous cement, ferruginous specks, and some plates of mica.	Ferruginous light brown.	142 8	15 to 20 ft. long, 2 ft. to 8 ft. in thickness.	0 5½	1 5	The Round Keep of Barnard Castle; Joint Stock Bank, and Market House, Barnard Castle.

SANDSTONES—*continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s. d.*	*s. d.*	
WHITBY COMPANY'S AISLABY, near Whitby, Yorkshire.	Mrs. Helen Noble, York.	Siliceous grains of moderate size, with an argillo-siliceous cement; some plates of mica and spots of carbon disseminated.	Light brown.	126 11	40×25 ft.	0 10	1 8	Some parts of Whitby Abbey; New Library at Cambridge; Baths and Town Hall at Whitby; cemetery at Highgate; Hungerford Market, &c.
WHITBY COMPANY'S EGTON QUARRIES, being *Arncliffe, Julian Park, Prod-dams*, and *Lease Rigge*, near Whitby.	Robert Cary Elwes, Esq., Great Billings, Northamptonshire.	- -	Pale, to dark brown.	- -	Arncliffe, 15×10×9 Prod-dams, 10×8×8 Lease Rigge, 10×6×5	0 11⅛	1 9⅜	Grosmont Abbey and Bridge; Egton Bridge; London and Birmingham Railway; Whitby and Pickering Railway.
WHITBY COMPANY'S SNEATON, near Whitby.	Charles Saunders, Esq., Sneaton Castle.	- -	- -	- -	24×9×3⅜	1 1	1 11	Parts of Whitby Abbey, and a portion of the parapet of Blackfriars Bridge, London.
WHITBY COMPANY'S NEWTON DALE, near Whitby.	R. W. Skelton, Esq., near Pickering.	- -	- -	- -	6 ft. by 4 ft. and 18 in.	0 10	1 8	Lewisham Church.

LIMESTONES.

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s. d.*	*s. d.*	
BEER, near Axminster, Devonshire.	Lord Rolle.	Chiefly carbonate of lime, friable, and with partial indurations.	Light tint of brown.	131 12	6 to 7 ft. long, 3 ft. wide, and 2 ft. thick.	- -	- -	In the churches of the vicinity; St. Peter's Church, Exeter, in exposed parts; Colyton Church, Charmouth, &c. &c.
CHILMARK, near Salisbury, Wiltshire.	Earl of Pembroke.	Carbonate of lime, with a moderate proportion of silica, and occasional grains of silicate of iron.	Light greenish brown.	153 7	10 cwt. to 3 tons. Several beds; thickest bed about 3 ft.	1 6 to 2 0	4 10 to 5 4	Salisbury Cathedral, Wilton Abbey, and many other ancient and modern buildings in the vicinity.
HOPTON WOOD, near Wirksworth, Derbyshire.	Philip Gall, Esq., Hapton Hall, near Wirksworth.	Compact carbonate of lime, with encrinal fragments abundant.	Warm light grey.	158 7	100 feet cube; beds vary in thickness from 3 to 10 ft.	3 0 to 4 0	4 10 to 5 10	At Chatsworth, Belvoir Castle, Trentham Hall, Drayton Manor, Birmingham Grammar School, &c.

LIMESTONES — *continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		s. d.	s. d.	
Seacombe, near Corfe Castle, Dorsetshire.	William John Bankes, Esq.	Semi-compact carbonate of lime, with fragments of shells.	Light brown.	151 0	The largest 6 to 8 ft., by 2 to 3 ft. by 3 to 4 ft.	1 2¼	1 9¼	Lighthouse at Margate; the Clockhouse, Dover Pier; prison at Winchester; at the West India Docks, forty years since; lighthouse now building on the Isle of Wight, &c.
Sutton, near Bridgend, Glamorganshire.	The Crown, and others.	Compact-carbonate of lime, highly crystalline.	Very light cream.	136 0	6 tons, and upwards; thickest bed 12ft.	- -	- -	Dunraven Castle, Ogmond Abbey, St. Donats Corty, Neath Abbey, and very ancient buildings in the adjoining counties.
Tottenhoe, near Dunstable, Bedfordshire.	James Jaly Wing.	Calcareous and argillaceous matter in about equal portions; structure fine.	Greenish white.	116 8	40 cubic ft. or upwards; 5 to 6 ft. long.	1 3	2 5	Dunstable Priory Curch, Luton, and many other churches in Bedfordshire and Hertfordshire; Woburn Abbey, Fonthill House, Ashridge, &c.

MAGNESIAN LIMESTONES.

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		s. d.	s. d.	
Bolsover, near Chesterfield, Derbyshire.	Earl Bathurst.	Chiefly carbonate of lime and carbonate of magnesia; semi-crystalline.	Light yellowish brown.	151 11	56 ft. cube, in beds from 8 in. to 2 ft. thick.	0 10	2 0	Southwell Church, and numerous buildings in the vicinity.
Brodsworth, near Doncaster, Yorkshire.	Lord Rendlesham.	Chiefly carbonate of lime and carbonate of magnesia, with sub-oolitic grains; friable.	Light brown tint.	133 10	Thickest bed 3 ft. 6 in.	- -	- -	Doncaster Old Church and Mansion-house, Brocklesby Hall, &c.
Cadeby, near Doncaster, Yorkshire.	Sir Joseph Copley, Bart.	Chiefly carbonate of lime and carbonate of magnesia, with sub-oolitic and irregularly formed oolitic grains; friable.	Cream.	126 9	Central beds (the best) 4 ft. thick.	- -	1 10	Day and Martin's, in High Holborn; almshouses at Edgware, &c.

MAGNESIAN LIMESTONES—*continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s. d.*	*s. d.*	
HUDDLESTONE, near Sherburne, Yorkshire.	Oliver Gascoigne, Esq., near Abberford.	Chiefly carbonate of lime and carbonate of magnesia, semi-crystalline.	Whitish cream.	137 13	50 to 250 cubic ft. Beds have been met with 4ft. thick.	2 0	3 0	York Minster, Selby Cathedral, Huddlestone Hall, Sherburne Church, Westminster Hall, Galeforth Hall, &c.
JACKDAW CRAIG, near Tadcaster, Yorkshire.	Sir Edward Vavasour, Bart.	Chiefly carbonate of lime and carbonate of magnesia.	Dark cream.	- -	Beds irregular, from a few inches to 3 feet.	- -	- -	York Minster, and probably most of the churches in York; also for the late restorations of York Minster.
ROCHE ABBEY, near Bawtry, Yorkshire.	Earl of Scarborough.	Chiefly carbonate of lime and carbonate of magnesia, with occasional dendritic spots of iron or manganese, semi-crystalline.	Whitish cream.	139 2	8 or 10 tons, thickest bed will work 2ft. 6 in.	0 8 to 1 6	2 1¼ 2 11¾	Roche Abbey Church, Tickhill Castle, and Church and Bridge, Sandbeck Hall, Selby Hall, two churches at Retford, Bawtry Church, and numerous churches in Yorkshire and Lincolnshire.
SMAWSE, near Tadcaster, Yorkshire.	Thomas Perrott, Esq.	Chiefly carbonate of lime and carbonate of magnesia, slightly crystalline.	Light yellowish brown.	127 8	Largest obtained 8·0 x 3·0 x 30.	0 7	2 1¼	Hull Old Church, Ripon Minster, St. Mary's Church and the minster at Beverley, the minster and several churches at York, and a new church at Appleby, in Lincolnshire.

OOLITIC STONES.

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s. d.*	*s. d.*	
ANCASTER, near Sleaford, Lincolnshire.	Mrs. Myers, Grantham.	Fine oolitic grains, cemented by compact, and often crystalline, carbonate of lime.	Cream.	139 4	3 to 5 tons, beds, 18 inches.	0 9 to 1 5	2 7	Wollaton Hall, Belvoir Castle, Belton House, and numerous mansions and churches in Lincolnshire.
BARNACK MILL, near Stamford, Northamptonshire.	Mr. John Martin, Ufford, near Stamford.	Carbonate of lime, compact and oolitic, with shells, often in fragments, coarsely laminated in planes of beds.	Light whitish brown.	136 12	Up to 30 ft., beds, 9 to 18 in.	1 0	2 3	Burleigh House, Peterborough Cathedral, Croyland Abbey, and the greater proportion of churches in Lincolnshire and Cambridgeshire.

OOLITIC STONES — *continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s.* *d.*	*s.* *d.*	
Bath Lodge Hill, Combe Down, near Bath, Somersetshire.	W. V. Jenkins, Esq., Combe Grove House, Bath.	Chiefly carbonate of lime, in oolitic grains.	Cream.	116 00	12 to 96 ft. cube. Thickest bed, 4½ ft.	0 6	- -	Restoration of Henry VII.'s chapel, twenty years since. Kennet and Avon Canal, and other works.
Bath Baynton Quarry, Box, near Chippenham.	Thomas Strong, of Box, near Chippenham.	Chiefly carbonate of lime, in moderately fine oolitic grains, with fragments of shells (weather bed).	Cream.	123 00	Up to 10 tons. Thickest bed, 5 ft.	0 7	1 11	Laycock Abbey, Longleat, Bowood, south front of Wilton House, Windsor Castle, &c.
Bath (Drewe's Quarry), Monkton Farleigh, near Bath.	Wade Brown, Esq., Monkton Farleigh.	Chiefly carbonate of lime, in oolitic grains of moderate size.	Cream.	122 10	120 to 125 ft. Several beds, the deepest about 4 ft. 2 in. thick.	0 6	1 10	Buckingham New Palace; St. James's Square, Bath.
Cranmore, near Doulting, Wiltshire.	- -	Carbonate of lime, with a few oolitic grains, and an abundance of small shells, commonly in fragments, often crystalline.	Light brown.	134 4	Of large size. The thickest beds will work 20 in.	0 7	- -	Cathedral of Wells, Glastonbury Abbey, &c.
Haydor, near Grantham, Lincolnshire.	John Archer Houblon, Esq., near Bishop's Stortford.	Carbonate of lime, with oolitic grains, often crystalline.	Brownish cream.	133 7	14 ft. × 3 ft. × 4 ft.	0 8	2 4	Lincoln Cathedral, Boston Church, Grantham Church, Newark Church, and most of the churches in the neighbourhood, and in the lower part of Lincolnshire; Culverthorpe House, Belvoir Castle, &c.
Ketton, in Rutlandshire, near Stamford.	Lord Northwick.	Oolitic grains of moderate size, slightly cemented by carbonate of lime.	Dark cream colour.	128 5	Up to 100 ft., beds vary very much: one 3 ft. 6 in. thick, called rag.	1 9	3 4	Cambridge, Bedford, Bury St. Edmund's, Stamford, London, &c.; many of the ancient and modern buildings at Cambridge; also in the modern works of Peterborough and Ely Cathedral, and at St. Dunstan's New Church, in London.
Portland (Trade Quarry), Island of Portland.	Messrs. Weston.	Oolitic carbonate of lime, with a few fragments of shells	Whitish brown.	- -	Any practicable size.	1 4½	2 3	Various public buildings in London.

OOLITIC STONES—*continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		s. d.	s. d.	
PORTLAND (KING BARROW EAST END QUARRY) adjoining WAYCROFT, Island of Portland.	Messrs. Weston.	Oolitic carbonate of lime, with a few fragments of shells.	Whitish brown.	- -	Any practicable size.	1 4½	2 3	Various public buildings in London.
PORTLAND (VERN-STREET QUARRY), Island of Portland.	Messrs. Weston.	Oolitic carbonate of lime, with a few fragments of shells.	Whitish brown.	134 10 top bed.	Any practicable size.	1 4½	2 3	Various public buildings in London.
PORTLAND (CASTLE'S QUARRY), Island of Portland.	Messrs. Weston.	Oolitic carbonate of lime, with a few fragments of shells.	Whitish brown.	- -	Any practicable size.	1 4½	2 3	Various public buildings in London.
PORTLAND (WAYCROFT QUARRIES), Island of Portland.	The Crown, on lease to Messrs. Stewards and Co.	Oolitic carbonate of lime, with disseminated fragments of shells.	Whitish brown.	135 8 top bed.	Any practicable size.	1 4½	2 3	Goldsmiths' Hall, Reform Club House, and other public buildings in London.
PORTLAND (MAGGOTT QUARRY).	The Crown, on lease to Messrs. Stewards and Co.	Oolitic carbonate of lime, with fragments of shells.	Whitish brown.	- -	Any practicable size.	1 4½	2 2	Various public buildings in London.
PORTLAND (GOSLING'S QUARRY).	Messrs. Stewards and Co.	Oolitic carbonate of lime, with fragments of shells.	Whitish brown.	126 13 Roach	Any practicable size.	1 4½	2 3	Several public buildings in London.
PORTLAND (GROVE QUARRY BOWERS).	Messrs. Stewards and Co.	Oolitic carbonate of lime, with numerous fragments of shells.	Whitish brown.	147 10 best bed. 145 9 carf.	Any practicable size.	1 4½	2 3	St. Paul's Cathedral, and several churches in London, built during the reign of Queen Anne.
PORTLAND (GROVE QUARRY, REDCROFT).	Messrs. Stewards and Co.	Oolitic carbonate of lime, with a few fragments of shells.	Whitish brown.	- -	Any practicable size.	1 4½	2 0	St. Paul's Cathedral, and many churches in London, of Queen Anne's reign.

Of the Portland stones, it is to be observed generally, that the dirt bed is full of fossil roots, trunks, and branches of trees, in the position of their former growth. The top cap is a white, hard, and closely compacted limestone. The skull cap is irregular in texture, and is a well-compacted limestone. The roach beds are always incorporated with the freestone beds, that invariably lie below them, and are full of cavities formed by the moulds of shells and the like. The top bed is the best stone, the bottom one ill cemented, and will not stand the weather. A middle or curf bed occurs only in the southernmost quarries on the east cliff; it is soft to the north, and hard to the south. The good workable stone in the east cliff quarries is generally less in depth than in the same bed in the west cliff quarries, but the east cliff stone is harder, more especially to the south of the island. The stone, even in the same quarries, varies considerably. That which contains flints will not stand the weather. The bottom bed on the west cliff is not a durable stone, though sold as a good stone in the London market. The best stone is in the north-eastern part of the island; the worst in the south-western part. The annual consumption of the whole of the quarries in the island is equal to an area of one acre of the good workable stone, or about 24,000 tons. The entire area unworked is about 2000 acres. There are 56 quarries in the island, and about 240 quarrymen employed, of which number Messrs. Stewards employ usually about 138.

OOLITIC STONES — *continued.*

Name of Quarry, and where situated.	Proprietor of Quarry.	Component Parts of Stone.	Colour.	Weight of a Cubic Foot in its ordinary State.	Weight of Block, and the Thickness procurable.	Price per Cubic Foot at the Quarry.	Price per Cubic Foot, delivered in London.	Where used.
				lb. oz.		*s. d.*	*s. d.*	
Taynton, or Teynton, near Burford, Oxon.	Lord Dynevor.	Carbonate of lime, partly oolitic and friable, with very small fragments of shells, irregularly laminated.	Streaky brown.	135 15	Any practicable size. Thickest bed, about 7 ft.	0 10 to 1 0	2 4	Blenheim, Cornbury Park, Barrington Park, the interior of St. Paul's and many other churches in London and Oxford, and in various bridges in Oxfordshire.
Wass, near Thirsk, Yorkshire.	Martin Stapleton, Esq.	Compact carbonate of lime, with oolitic grains and an argillo-calcareous cement; carbon disseminated.	Brown.	141 11 soft. 162 8 hard.	Beds variable, about 16 in.	- -	- -	West front and a large proportion of Byland Abbey.
Windrush, near Burford, Gloucestershire.	Lord Shelburne.	Fine oolitic grains, with calcareous cement, and a few fragments of shells.	Cream.	118 2 soft. 135 15 hard.	5 to 40 ft. Thickest bed, 2 ft. 6 in.	0 8	2 7	Windrush Church, Barrington House, and all the old buildings within many miles of the quarry.

1665. The following very useful enumeration of the stones used in buildings of the island, arranged under that head, and divided into the sorts of stone employed in them, we add, *verbatim*, from the Report which we have so much used. The heads are under Sandstone buildings, Limestone buildings, and Magnesian Limestone buildings

SANDSTONE BUILDINGS.

Bakewell, Derbyshire. The houses generally are of sandstone, and in fair condition. A new bank now erecting of sandstone from Bakewell Edge.

Bakewell Church (14th century), of a sandstone of the vicinity, very much decomposed.

Barnard Castle, Durham (14th century). Circular keep, apparently of Stenton stone, in excellent condition. In modern works, the Joint Stock Bank and Market-house of Stenton stone, in good condition.

Belper New Church, Derbyshire. Built 10 years since, of sandstone from Hungerhill, in an incipient state (in parts) of decomposition.

Blandford Parish Church, Dorsetshire (1769). Of a green siliceous fine-grained sandstone, the dressings being of a stone similar to the Portland oolite; the former much decomposed; the latter in very good condition. Town Hall, about 80 years old, of stone similar to the Portland oolite, in good condition.

Brancepeth Castle, Durham. Of ancient date, of sandstone of the vicinity; recently restored extensively; older parts in various states of decomposition.

Briavel's, St., Castle, Glocestershire. In ruins (13th or 14th century). Entrance gateway (the chief remains of the castle) built of red sandstone, decomposed.

Bristol Cathedral (13th and 14th centuries). Built of red sandstone and a yellow limestone (magnesian?) strangely intermixed; the red sandstone in all cases decomposed, the limestone more rarely decayed; the tracery, &c. of the windows, which are of the limestone, are in good condition; but the pinnacles and other dressings, which are of the same material, are much decomposed. The east end of the cathedral is a remarkable instance of the decay and preservation of the two stones employed. Norman gateway, west of the cathedral (the upper part of the 15th century); the Norman archway and its enrichments, which are of a very florid character, built of yellow limestone (magnesian?), in excellent condition.

Byland Abbey (12th century). In part of a siliceous grit (principally in the interior), and in part (chiefly on the exterior) of a compact oolite, from the Wass quarries in the vicinity. The west front, which is of the oolite, is in perfect condition, even in the dog's-teeth and other florid decorations of the doorways, &c. This building is *covered generally* with lichens.

Carlisle. Ancient buildings: Cathedral (13th century), of red sandstone, in various states of decomposition. Modern buildings: Many of red sandstone, more or less in a state of decomposition.

Castle Howard, Yorkshire. Built generally of a siliceous fine-grained sandstone from the park; generally in good condition, but in some parts, such as the parapets, cupolas, and chimney shafts, much decomposed. The pilasters of the north front from a quarry at Appleton; in good condition, except where subjected to alternations of wet and dry, as in the plinths, where there are signs of decomposition. The stables are of Appleton stone, and in good condition.

Chatsworth House, Derbyshire. Original house built of Bell Crop sandstone from Bakewell Edge, not in very good condition, particularly in the lower parts of the building. In the recent additions the same stone is employed, together with that of Bailey Moor and Lindrop Hill.

Chepstow Castle, Monmouthshire (11th and 12th centuries, with additions of the 14th century). Of mountain limestone and old red sandstone; the former in good condition; the latter decomposed. Dressings of doors, windows, archways, and quoins are for the most part of magnesian limestone, in perfect condition; the remainder is of red sandstone, and is generally much decomposed. Chapel (of the 12th century); mouldings and carvings of the windows, &c., which are of magnesian limestone, are in perfect condition.

Coxwold Church, Yorkshire (15th century). Generally of fine siliceous grit of the vicinity, and in part of a calcareous nature. Tower in good condition; porch decomposed; lichens abundant on the north side.

Derby. St. Peter's Church (13th century), of the variegated coarse sandstone of the vicinity, similar to that of Little Eaton. The whole in bad condition; but the red stones less so than the grey or white. St. Almund's Church (of the 14th century), of a coarse sandstone of the vicinity, in a very decomposed state, to the obliteration of the mouldings and other details; it has lately been scraped and painted, to preserve it from further destruction. All Saints Church (tower of the 15th century), of sandstone, similar to that of Duffield Bank, partly in fair condition, and partly much decomposed, particularly the great western entrance. The body of the church, built 110 years since, of sandstone, in part decomposing. Modern buildings: Town Hall, of sandstone from Morley Moor, built a few years since, in very good condition.

Durham Cathedral (11th and 12th centuries). Of a sandstone of the vicinity, elected indiscriminately, and in all stages of decomposition; few stones are quite perfect. Castle (of the 11th century). Of similar stone, and in a similar state.

Easby Abbey, Yorkshire (13th and 14th centuries). Of sandstone of the vicinity; mouldings and carvings decomposed and in part obliterated. Walls built very rudely, and in various states of decomposition; some parts, however, maintain their original surface.

Eccleston Abbey, Yorkshire (13th century). Of stone similar to that of the Stenton quarry. The mouldings and other decorations, such even as the dog's-teeth enrichments, are in perfect condition.

Edinburgh. Ancient buildings: Holyrood Chapel (12th century), of sandstone from the vicinity, in part much decomposed; in other parts, such as the west door, almost perfect. The palace (built in the 16th and 17th centuries) of similar stone, generally in good condition, the older parts being slightly decomposed. The oldest part of the Tron Church (1641), of sandstone, much decomposed. A house on the Castle Hill (1591), of sandstone, only slightly decomposed.

Modern buildings, wholly erected of sandstones from the Cragleith, Red Hall, Humbie, and Binnie quarries, for the most from the first-mentioned quarry. None of them exhibit any appearance of decomposition, with the exception of ferruginous stains, which are produced upon some stones. Among the oldest is the Registry Office, which is of Cragleith stone, and built above sixty years since; it is in a perfect state.

Fountain's Abbey, Yorkshire (11th and 12th centuries, with additions of the 16th century). Of coarse sandstone of the vicinity, generally in bad condition, particularly the west front, which is much decomposed. The nave and transept, which are the earliest portions of the building, are the best preserved.

Fountain's Hall, Yorkshire (1677). Of sandstone of the vicinity, and magnesian limestone in the dressings. The whole in fair condition.

Forest of Dean, Gloucestershire. Park End new church, built fifteen years since, of sandstone, similar to that of Colford. No appearance of decomposition.

Glasgow. Ancient buildings: High Church (12th century), sandstone of the vicinity, generally very much decomposed, particularly on the south side Old quadrangle of the College (James II.), of sandstone, decomposed.

Modern buildings: Hunterian Museum (1804); superstructure said to be of stone from the President quarry; slight traces of decomposition on the south-west front. The basement of another sandstone, in a more advanced state of decomposition; other parts of the building are in an almost perfect state. The other buildings are generally erected of stone from the Giffneuch and other quarries in the immediate neighbourhood, except the new Exchange buildings, which are of stone from the Humbie quarry, thirty miles from Glasgow, recently erected, in which there are not any apparent symptoms of decomposition.

Gloucester Cathedral (Norman for the greater part, altered and cased in the 15th century), built of a fine-grained and ill-cemented oolite, a shelly oolite, and a red sandstone (north side) intermixed, of which the former constitutes the greater portion. The tower (15th century), of shelly oolite, in perfect condition. The early turrets of the south transepts are also in good condition. The body of the building is much decomposed. The great cloister is built of the same materials as the cathedral. The moulded and decorated work is in good condition, the other parts are more or less decomposed. The small cloister is built of a fine oolite with a compact cement, and is in good condition. The New Bridge, of Whitchurch sandstone, parapets of Ruordean fine-grained sandstone, in good condition.

Haddon Hall, Derbyshire (15th and 16th centuries). Of a fine-grained sandstone, similar to that of Lindrop Hill. The dressings, parapets, chimney shafts, quoins, &c. are wrought and rubbed; the remainder of the walls is of rough walling. The whole in fair condition.

Harrowgate. Cheltenham Pump Room, of sandstone from Woodhouse, near Leeds. Built recently. In good condition. Swan Hotel and other modern buildings, of a coarse sandstone of the vicinity; generally in good condition.

Hardwicke Hall, Derbyshire. (1597). Of a fine-grained sandstone, chiefly from a quarry in the hill on which the house is built, intermixed with a calciferous grit, similar to that of Mansfield; generally in good condition. The ashler is in parts decomposed, especially where it is set on edge.

Howden Church, Yorkshire (15th century); partly of magnesian limestone, of a deep yellow colour, and partly of a coarse siliceous grit, of a ferruginous colour. Dressings and enrichments and the central tower are of the former stone; generally decomposed, particularly at the top of the tower. The other parts of the building, which are of the grit, are very much decomposed.

Kirkstall Abbey, Yorkshire (11th century). Of coarse sandstone of the vicinity, in various stages of decomposition according to the aspect. The east side is in fair condition; some of the zig-zag enrichments and early capitals and other enrichments of mouldings are in perfect condition. The windows of the chancel and tower (inserted in the 16th century) of a yellow sandstone, are for the most part gone, and what remains is much decomposed.

Mansfeld Town Hall, Nottinghamshire. Built three years since, of magnesio-calciferous sandstone from Mansfield: no appearance of decomposition.

Newcastle-upon-Tyne. Ancient buildings: St. Nicholas' Church (14th century), of sandstone of the vicinity, similar to that of the Heddon Quarry, very much decomposed. Parts restored within the last century, with the same stone, now decomposing. The upper part of the tower and spire restored within the last five years, and painted to preserve the stone from decay. Other ancient buildings, of the same stone, more or less in a state of decomposition, according to the date of their erection.

Modern buildings, built within the last 25 years, of sandstone from the Felling and Church quarries at Gateshead and the Kenton quarry: parts already show symptoms of decomposition.

Pontefract Castle, Yorkshire (14th century). Built generally of a coarse grit, of a dark brown colour, occasionally mixed with an inferior magnesian limestone. The whole in a very decomposed state, more particularly the sandstone, in which all traces of the original surface are effaced. Fragments of magnesian limestone are embedded in several parts of the walls, with mouldings of the 12th century, in perfect condition.

Raby Castle, Durham (14th century). Of sandstone of the vicinity: parts in a perfect state, others slightly decomposed.

Richmond Castle, Yorkshire (11th century). The keep, of sandstone, similar to that of Gatherly Moor, generally in good condition; mouldings and carvings in columns of window in a perfect state.

Ripon, Yorkshire. An obelisk in the market-place (1781), of coarse sandstone, much decomposed in laminations parallel to the exposed faces.

RIPON CATHEDRAL. Lower part, east end, and south-east angle (Norman), of coarse sandstone of the vicinity, in good condition. The west front, the transepts, and tower (of the 12th and 13th centuries), of the coarse sandstone of the vicinity, in fair condition. The mouldings, although generally decomposed, are not effaced. The dog's-teeth ornaments in most parts nearly perfect. The aisles of the naves, the clerestory, and the choir (of the 14th and 15th centuries), of coarse sandstone and magnesian limestone intermixed, not in good condition; the latter stone, on the south side, often in fair condition. The lower parts of the building generally, but particularly the west fronts, which are of coarse sandstone, are very much decomposed.

RIVAULX ABBEY, Yorkshire (12th century). Of a sandstone at Hollands, one mile from the ruins; generally in excellent condition. West front slightly decomposed; south front remarkably perfect, even to the preservation of the original toolmarks.

SHAFTESBURY, Dorsetshire. St. Peter's Church (15th century). Of a green siliceous sandstone, from quarries half a mile south of the church. The whole building much decomposed. The tower is bound together by iron, and is unsafe, owing to the inferior quality of the stone.

SPOFFORTH CASTLE, Yorkshire (14th century). Of coarse red sandstone; more or less, but generally much, decomposed. The dressings of the windows and doors, of a semi-crystalline magnesian limestone, are in perfect state, the mouldings and enrichments being exquisitely sharp and beautiful.

TINTERN ABBEY (13th century). Considerable remains of red and grey sandstones of the vicinity, in part laminated. In unequal condition, but for the most part in perfect condition; covered with grey and green lichens.

TISBURY CHURCH (13th and 14th centuries; the lower part of the tower of the 12th century). Of calciferous limestone from Tisbury. The dressings are composed of stone throughout, in perfect condition. The ashlar variable; in part much decomposed; the undecomposed portions are covered with lichens. Tombstones in the churchyard generally in good condition, some being more than a century old. The houses of the village built generally of the Tisbury stone, and are in very good condition. The whole covered with lichens.

WAKEFIELD PARISH CHURCH, Yorkshire (tower and spire of the 16th century). Of sandstone, much decomposed. The body of the church, of recent date, of sandstone, strongly laminated, and generally decomposed between the laminæ.

WHITBY ABBEY (13th century). Of stone similar to that of Aislaby Brow, in the vicinity; generally in good condition, with the exception of the west front, which is very much decomposed. The stone used is of two colours, brown and white; the former, in all cases, more decomposed than the latter. The dog's-teeth and other enrichments in the east front are in good condition.

LIMESTONE BUILDINGS.

BATH. Abbey church (1576), built of an oolite in the vicinity. The tower is in fair condition. The body of the church, in the upper part of the south and west sides, much decomposed. The lower parts, formerly in contact with buildings, are in a more perfect state; the reliefs in the west front of Jacob's ladder are in parts nearly effaced. Queen's Square, north side, and the obelisk in the centre, built above 100 years since, of an oolite with shells, in fair condition. Circus (built about 1750), of an oolite in the vicinity, generally in fair condition, except those portions which have a west and southern aspect, where the most exposed parts are decomposed. Crescent (built above 50 years since), of an oolite of the vicinity, generally in fair condition, except in a few places, where the stone appears to be of inferior quality.

BRISTOL CATHEDRAL (of the 13th and 14th centuries). Built of red sandstone and apparently a yellow limestone (magnesian?) strangely intermixed. The red sandstone in all cases decomposed; the limestone more rarely decayed. The tracery, &c. of the windows, which are of the limestone, are in good condition, but the pinnacles and dressings of the same material much decomposed. The east end of the cathedral is a remarkable instance of the decay and preservation of the two stones employed. Norman gateway, west of the cathedral (the upper part of the 15th century), the Norman archway and its enrichments, which are of a very florid character, built of yellow limestone (magnesian?), in excellent condition.

——, **ST. MARY REDCLIFFE** (tower of the 12th century; body of the church of the 15th century). Of oolitic limestone, from Dundry; very much decomposed.

BURLEIGH HOUSE (15th century). Of a shelly oolite (Barnack rag), in excellent condition throughout. The late additions are of Ketton stone.

BYLAND ABBEY, Yorkshire (12th century). In part of a siliceous grit (principally in the interior), and in part (chiefly on the exterior) of a compact oolite, from the Wass quarries in the vicinity. The west front, which is of the oolite, is in perfect condition, even in the dog's-teeth and other florid decorations of the doorways, &c. This building is generally covered with lichens.

Colley Weston Church, Northamptonshire (14th century). Of a shelly oolite (Barnack rag), in perfect condition throughout.

Dorchester. St. Peter's Church (15th century). Of laminated oolite, somewhat similar to that of Portland, and of a shelly limestone, somewhat resembling that of Hamhill. The latter used in pinnacles, parapets, and dressings. The whole in a decomposed state.

Glastonbury — Abbey. Joseph of Arimathea's Chapel. Considerable ruins; Norman, of shelly limestone, similar to that of Doulting; generally in good condition; the zig-zag and other enrichments perfect; the capitals of the columns, corbels, &c. are of blue lias, much decomposed, and in some cases have disappeared. The *Church.* Considerable remains of the choir, and a small portion of the nave (11th century), of shelly limestone, similar to that of Doulting, in good condition. *St. Benedict's Parish Church* (14th century). Of limestone, similar to that of Doulting, in good condition. *St. John the Baptist's Parish Church* (15th century). Of stone similar to that of Doulting, generally in fair condition.

Glocester — Cathedral, (Norman for the greater part, altered and cased in the 15th century). Built of a fine-grained and ill-cemented oolite, a shelly oolite, and a red sandstone (north side) intermixed, the former constituting the greatest portion of the edifice. The tower (15th century), of shelly oolite, in perfect condition. The early turrets of the south transept are also in good condition. The body of the building is much decomposed. The great cloister is built of the same materials as the cathedral. The moulded and decorated work is in good condition; the other parts are more or less decomposed. The great cloister is built of a fine oolite, with a compact cement, and is in good condition. *St. Nicholas's Church* (body Norman; tower and spire, 15th century), of a shelly and inferior kind of oolite intermixed, and in unequal condition. *St. Michael's Church* (15th century), built of same stone as that of St. Nicholas, and in the same condition.

Grantham Church (13th century). Lofty tower and spire at the west end. Built of an oolite, similar to that of Ancaster, in good condition, more especially the tower, except as to some portions of the base mouldings.

Ketton Church, Rutlandshire. (West entrance door, Norman; tower of the 12th or 13th century; nave, aisles, and chancel of the 14th century). Of a shelly oolite (Barnack rag), in good condition. Dog's-teeth, carved corbels, and other enrichments in a perfect state.

Kettering Church (14th and 15th centuries). Of a shelly oolite, fine-grained, the greater portion resembling Barnack rag. The tower and spire in perfect condition. The body of the church in parts slightly decomposed.

Kirkham Priory, Yorkshire (13th century). Inconsiderable remains. The western front and great entrance slightly decomposed throughout; the portions which remain of the body of the church very perfect, but many of the stones are much decomposed. The stone is very similar to that of the Hildenly quarry. The whole is covered with lichens.

Lincoln Cathedral (the minster generally of the 12th and 13th centuries). Of oolitic and calcareous stone of the vicinity; generally in fair condition, more especially the early portions of the west front. The ashler and plain dressings of the south front are, however, much decomposed. The mouldings and carvings of the east front are in a perfect state. *Roman Gate*, of a ferruginous oolite, in fair condition. *The Castle Gateway* (13th century), of an oolitic limestone; ashler much decomposed, dressings perfect.

Melton Old Church, Yorkshire (12th century). Light semi-compact limestone, similar to that of the Hildenly quarry; generally in good condition, particularly the great west door (of the 11th century), where the zig-zag and other enrichments are perfect. Some stones are much decomposed.

Montacute, Somersetshire — Parish Church (15th century). Of Hamhill stone, in perfect condition, covered with lichens. The Abbey (15th century). Supposed abbot's house and gateway, of Hamhill stone, in good condition. *Montacute House* (17th century), of Hamhill stone, in excellent condition.

Mastock Church, Somersetshire (15th century). Of a shelly ferruginous brown limestone from Hamhill, in good condition, except the plinth and base mouldings, which are much decomposed. Covered with lichens.

Newark Church (15th century; the tower, in part, of the 12th century). Of an oolite, similar to that of Ancaster; generally in fair condition, with the exception of parts of the base mouldings. The building is covered with a grey lichen. *The Castle* (Norman, with additions in the 15th century). Chiefly of sandstone of the vicinity; in unequal condition. A large portion of the dressings of the windows, &c. are of oolite, probably from Ancaster. *Town Hall* (50 or 60 years old). Built of the Ancaster oolite; in good condition; in some blocks, however, there is an appearance of lamination, where decomposition has to a slight extent taken place.

Oxford Cathedral, Norman (12th century). Chiefly of a shelly oolite, similar to that of Taynton; Norman work in good condition, the latter work much decomposed. *Merton College Chapel* (13th century). Of a shelly oolite, resembling Taynton stone; in good condition generally. *New College Cloisters* (14th century). Of a shelly oolite (Taynton), in good condition. The whole of the colleges, churches, and other public buildings of Oxford, erected within the last three centuries, are of oolitic limestone from Heddington, about one mile and a half from the university, and are all, more or less, in a deplorable state of decomposition. The plinth, string-courses, and such portions of the buildings as are much exposed to the action of the atmosphere, are mostly of a shelly oolite from Taynton, fifteen miles from the university, and are universally in good condition.

Paul's, St., Cathedral, London (finished about 1700). Built of Portland oolite, from the Grove quarries on the east cliff. The building generally in good condition, especially the north and east fronts. The carvings of flowers, fruit, and other ornaments are throughout nearly as perfect as when first executed, although much blackened; on the south and west fronts, larger portions of the stone may be observed of their natural colour than on the north and east fronts, occasioned by a very slight decomposition of the surface. The stone in the drum of the dome, and in the cupola above it, appears not to have been so well selected as the rest; nevertheless scarcely any appreciable decay has taken place in those parts.

Pickering Church, Yorkshire (13th and 14th centuries). Oolite rock of the neighbourhood; very much decomposed; the windows, mullions, and buttress angles obliterated.

Pickering Castle (14th century). The walls of the oolite of the neighbourhood, and the quoins of a siliceous grit. The whole in fair condition.

Portland, Dorsetshire — New Church (built 1766), of Portland oolite, fine roach; in a perfect state, still exhibiting the original tool marks. Wakeham Village, Tudor House, of Portland oolite, in excellent condition. *Old Church*, in ruins, near Bow and Arrow Castle (15th century), of Portland oolite, resembling top bed; in very good condition; original chisel marks still appear on the north front. *Bow and Arrow Castle.* Considerable remains of the keep, many centuries old, of Portland oolite; the ashlar resembles the top bed, and is in perfect condition; the quoins and corbels of the machicolated parapet appear to be of the cap bed of Portland oolite, and are in good condition.

Salisbury Cathedral (13th century). Of siliciferous limestone from Chillmark quarry. The entire building is in excellent condition, except the west front, which in parts is slightly decomposed. The building generally covered with lichens.

Sandysfoot Castle, near Weymouth (temp. Hen. VIII.). Considerable remains of keep, chiefly of Portland oolite, partly of the top bed and partly of the fine roach; generally in excellent condition, with the exception of a few and apparently inferior stones. The inside ashlar of the walls is of large-grained oolite, apparently from the immediate vicinity of the castle, much decomposed.

Somerton Church, Somersetshire (14th century). Built chiefly of blue lias; the quoins, buttresses, parapets, and other dressings of a coarse ferruginous shelly limestone, in various stages of decay. The parapet of the clerestory of a lighter-coloured stone, in good condition.

Stamford — St. Mary's Church (13th century). Of a shelly oolite (Barnack rag), in fair condition. *St. John's Church* (14th century). Of similar stone, ill selected, and consequently decomposed in parts and in laminations, according to the direction of the beds of shells. *St. Martin's Church* (14th century). Of similar stone, in good condition. *All Saints* (lower part of the body of the church 13th century; the remainder 15th century). Tower and spire in fine condition; body of the church decomposed. *Standwell's Hotel*, built twenty-four years since of an oolite similar to that of Ketton; in perfect condition. *St. Michael's New Church.* Built four years since; no appearance of decomposition.

Wells, The Cathedral. West front (13th century), upper part of tower (14th century), of shelly limestone, similar to that of Doulting, generally decomposed, but not to any great extent. North flank (porch and transept 13th century, the remainder of the 14th century), of similar stone, in good condition, except lower part of flank and west tower. The central tower (of the 14th century) in very good condition. South side of the cathedral generally in good condition. *Chapter House* (13th century, with additions of the 15th century). The whole in good condition excepting the west front of the gateway, which is decomposed. Close gates (15th century) much decomposed, but especially on the south and south-west. The cloisters (15th century) generally decomposed, particularly the mullions and tracery.

Westminster Abbey (13th century). Built of several varieties of stone, similar to that of Gatton or Ryegate, which is much decomposed, and also of Caen stone, which is generally in bad condition; a considerable portion of the exterior, especially on the north side, has been restored at various periods, nevertheless abundant symptoms of decay are apparent. The cloisters, built of several kinds of stone, are in a very mouldering condition, except where they have been recently restored with Bath and Portland stones. The west towers, erected in the beginning of the 18th century with a shelly variety of Portland oolite, exhibit scarcely any appearance of decay. Henry the Seventh's Chapel, restored about twenty years since with Combe Down Bathstone, is already in a state of decomposition.

Windrush Church (15th century). Of an oolite from the immediate vicinity; in excellent condition. A Norman door on the north side, enriched with the bird's-beak and other characteristic ornaments, is in perfect condition. Tombstones in the churchyard, very highly enriched and bearing the dates of 1681, 1690, apparently of Windrush stone, are in perfect condition.

Wyke Church, Dorsetshire (15th century). Of oolite, similar to Portland, the whole in good condition, except the mullions, tracery, and dressings of doors and windows, which are constructed of a soft material, and are all decomposed. On the south side, the ashler is in part covered with rough-cast. The entire building is thickly covered with lichens.

MAGNESIAN LIMESTONE BUILDINGS.

Beverley, Yorkshire. The minster (12th, 13th, and 14th centuries), of magnesian limestone from Bramham Moor, and an oolite from Newbold; the former, which is used in the west tower, central tower, and more ancient parts of the minster, generally in good condition; but in other parts of the building the same material is decomposed. The Newbold stone, chiefly employed on the east side, is altogether in a bad condition. Some of the pinnacles are of Oulton sandstone, and are in bad condition. The building is partly covered with lichens. *St. Mary's Church* (14th century), now in course of restoration, of magnesian limestone and oolite, supposed to be from Bramham Moor and Newbold, respectively. The ancient parts are in a very crumbling state, even to the obliteration of many of the mouldings and enrichments.

Bolsover Castle, Derbyshire (1629). Mostly in ruins; of magnesian limestone of several varieties, and of a calcareous fine-grained sandstone. The dressings, which are generally of sandstone, are much decomposed, in some instances to the entire obliteration of the mouldings and other decorations, and to the destruction of the form of the columns, rustications, &c. Most of the string courses, a portion of the window dressings, and the ashler, which are of magnesian limestone, are generally in excellent condition.

Bolsover Church, Derbyshire (15th century). Of a magnesio-calciferous sandstone, more or less in a decomposed state throughout.

Chepstow Castle, Monmouthshire (11th and 12th centuries, with additions of the 14th century). Of mountain limestone and old red sandstone; the former in good condition, the latter decomposed. Dressings of door, window, archway, and quoins are for the most part of magnesian limestone, and in perfect condition. The remainder is of red sandstone, and is generally much decomposed. Chapel (of the 12th century), mouldings and carvings of windows, &c., which are of magnesian limestone, in perfect condition.

Doncaster (Old) Church (15th century). Of an inferior magnesian limestone, generally much decomposed, more especially in the tower, and on the south and west sides; now under general and extensive repair.

Hemingborough Church, Yorkshire (15th century). Of a white crystalline magnesian limestone. The entire building is in a perfect state, even the spire, where no traces of decay are apparent.

Howden Church, Yorkshire (15th century). Partly of magnesian limestone of a deep yellow colour, and partly of a coarse siliceous grit of a ferruginous colour. Dressings and enrichments, and the central tower, are of the former stone, generally decomposed, particularly at the top of the tower. The other parts of the edifice, built of the grit, are very much decomposed.

Huddlestone Hall, Yorkshire (15th century). Of semi-crystalline magnesian limestone from the neighbouring quarry. In excellent condition, even to the entire preservation of the mouldings of the chapel window in the south-west front. The outer gate piers in the fence wall, also of magnesian limestone, very much decomposed.

Knaresborough Castle, Yorkshire (12th century). Magnesian limestone, carious in part;

generally in very good condition, except on the south and south-west portions of the circular turrets, where the surface is much decomposed. The mouldings generally are in a perfect state. The joints of the masonry, which is executed with the greatest care, are remarkably close. The stone of the keep, which is of a deep brown colour, and much resembles sandstone, is in good condition, especially on the south-west side.

Koningsborough Castle, Yorkshire (Norman). Coarse-grained and semi-crystalline magnesian limestone, from the hill eastward of the castle; in perfect condition. The masonry is executed with great care, the joints very close, but the mortar within them has disappeared.

Ripon Cathedral. Lower part, east end, south-east angle (Norman), of coarse sandstone from the vicinity, in good condition. The west front, the transepts, and tower (of the 12th and 13th centuries), of coarse sandstone of the vicinity, in fair condition. The mouldings, although generally decomposed, are not effaced. The dog's-teeth ornament in most parts nearly perfect. The aisles of the nave, the clerestory, and the choir (of the 14th and 15th centuries), of coarse sandstone and magnesian limestone intermixed, not in good condition. The latter stone, on the south side, often in fair condition. The lower parts of the building generally, particularly the west fronts, which are of coarse sandstone, are much decomposed. An obelisk, in the market-place (1781), of coarse sandstone, is much decomposed, and in laminations parallel to the exposed faces.

Robin Hood's Well, Yorkshire (1740). A rusticated building, of magnesian limestone, in perfect condition.

Roche Abbey, Yorkshire (12th century). Inconsiderable remains, of semi-crystalline magnesian limestone from the neighbouring quarry, generally in fair condition. The mouldings and decorated portions are perfect. Gate-house (12th century) generally decomposed, with the exception of the dressings and mouldings, which are perfect.

Selby Church, Yorkshire (nave and lower part of the tower of the 11th century; the west front and aisles of the 12th century; and the choir with its aisles of the 14th century). The Norman portion of the building, which is of grey magnesian limestone, is in excellent condition, particularly the lower part. The early English portions of the building are also of magnesian limestone, and in a partially decomposed state. The later portions of the building, which also are of magnesian limestone, are much decomposed and blackened.

Southwell Church, Notts (of the 10th century). Of magnesian limestone, similar to that of Bolsover Moor, in perfect condition. The mouldings and enrichments of the doorway appear as perfect as if just completed. The choir, which is of the 12th century, and built of a stone similar to that of Mansfield, is generally in good condition.

Spofforth Castle, Yorkshire (14th century). Of coarse red sandstone, generally much decomposed. The dressings of the windows and doors, of a semi-crystalline magnesian limestone, are in a perfect state, the mouldings and enrichments being eminently sharp and beautiful.

Studley Park, Yorkshire. Banquetting house, about 100 years old, of yellowish magnesian limestone, in perfect condition.

Thorpe Abbey Village. The houses generally of this village are built of magnesian limestone from the vicinity; they are in excellent condition, and of a very pleasing colour.

Thorpe Salvin, near Worksop. Manor-house (15th century), in ruins. Of a siliciferous magnesian limestone and a sandstone, in unequal condition; the quoins and dressings are generally in a perfect state. *Parish Church* (15th century), also of a siliciferous variety of magnesian limestone and a sandstone, in unequal but generally fair condition. A Norman doorway under the porch is well preserved.

Tickhill Church, Yorkshire, (15th century). Of magnesian limestone, in excellent condition. The lower part of the tower (of the 12th century) also in fair condition.

York. *Ancient Buildings:* Cathedral (transepts, 13th century; tower, nave, &c., 14th century). Of magnesian limestone, from Jackdaw Craig. West end and towers restored thirty years since; they are generally in fair condition, but some of the enriched gables and other decorations are obliterated. The transepts are in many places much decomposed, especially in the mouldings and enrichments. The central tower is generally in good condition, but several of the enriched parts are decomposed. *St. Mary's Abbey* (12th century), of magnesian limestone. West front of the church generally much decomposed; the north flank in better condition, but in parts much decomposed. The gateway, which is of Norman origin, is in fair condition. *Roman Multangular Tower.* Built of small stones; such as are of magnesian limestone are in good condition. *St. Denis's Church.* Norman doorway, of magnesian limestone; south side highly enriched with zig-zag and other ornaments; the columns are gone; the parts which remain are in good condition. *St. Margaret's Church* (15th century), of magnesian limestone; east front much exposed, and in good condition. The porch is of Norman date, and has been reconstructed; four bands of enrichment in the head, in tolerably fair condition, but many stones, particularly those of a deep yellow brown colour, are much decomposed. *The other churches of York* (which are of the 14th and 15th centuries) are built of magnesian limestone, and are generally in an extremely decomposed state; in many instances all architectural detail is obliterated. *Modern Buildings:* THE MUSEUM, of Hackness sandstone, built nine years since, much decomposed wherever it is subject to the alternation of wet and dry, as at the bottom of the columns of the portico, plinth, &c. THE CASTLE (recently erected); the plinth of the boundary wall (which is of Bramleyfall sandstone) already exhibits traces of decomposition. *York Savings Bank.* Huddersfield stone (?), in good condition.

WORKSOP CHURCH (principally of the 13th century), of a siliciferous variety of magnesian limestone and of a sandstone; in very unequal condition. Some parts are very much decomposed, whilst others are in a perfect state.

1666. Valuable as the above Report is, there remain points, perhaps minor ones, which are still desiderata for the architect; but we are, nevertheless, much indebted to all concerned in its production. It contains a sufficiently ample account of the principal quarries of the country to guide the architect in the choice of the material, and is almost the only thing that the government of this country has ever done to advance architecture as a science: for it, as an art, it does not appear probable much will be done till things are very much changed. We shall close our account of the stone of England with a very useful table of the chemical analysis of sixteen specimens of stone, which were examined by Messrs. Daniel and Wheatstone, whose names are sufficient to impart a value to it in the mind of every scientific person.

	SANDSTONES.					MAGNESIAN LIMESTONES.				OOLITES.				LIMESTONES.		
	Craigleith.	Darley Dale (Stancliffe).	Heddon.	Kenton.	Mansfield, or C. Lindley's Red.	Bolsover.	Huddlestone.	Roach Abbey.	Park Nook.	Ancaster.	Bath Box.	Portland.	Ketton.	Barnack.	Chilmark.	Ham-hill.
Silica - -	98·3	96·40	95·1	93·1	49·4	3·6	2·53	0·8	0·0	0·0	0·0	1·20	0·0	0·0	10·4	4·7
Carbonate of lime -	1·1	0·36	0·8	2·0	26·5	51·1	54·19	57·5	55·7	93·59	94·52	95·16	92·17	93·4	79·0	79·3
Do. of magnesia -	0·0	0 0	0·0	0·0	16·1	40·2	41·37	39·4	41·6	2·90	2·50	1·20	4·10	3·8	3·7	5·2
Iron alumina -	0·6	1·30	2·3	4·4	3·2	1·8	0·30	0·7	0·4	0·80	1·20	0·50	0·90	1·3	2·0	8·3
Water and loss -	0·0	1·94	1·8	0·5	4·8	3·3	1·61	1·6	2·3	2·71	1·78	1·94	2·83	1·5	4·2	2·5
Bitumen - -	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	A trace.	Do.	Do.	Do.	A trace.	Do.	Do.
	Specific Gravities.															
Of dry masses -	2232	2628	2229	2247	2338	2316	2147	2134	2138	2182	1839	2145	2045	2090	2481	2260
Of particles -	2646	2993	2643	2625	2756	2833	2867	2840	2847	2687	2675	2702	2706	2627	2621	2695
	Cohesive Powers.															
	111	100	56	70	72	117	61	55	61	33	21	30	36	2 5	101	57

1667. The above table gives the results of the chemical analysis of sixteen specimens of stone, arranged according to their respective classes. The names of the quarries are inserted under the general divisions of the different species of stone, and the specimens were considered as fair average samples of the workable stone in such quarries. The experiments were conducted by Messrs. Daniel and Wheatstone. In subsection 1500. we have already supplied a table, to which the reader is referred for the crushing weights of the stones therein mentioned; and that, added to the information which the immediately preceding pages supply, will, we trust, be all that is necessary on this branch of the subject under consideration.

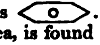
SECT. II.

GRANITE.

1668. Among the primitive rocks of the globe, whose period of creation is considered by geologists as antecedent to that of organic beings, is that of granite, whose use in architecture seems to bid defiance to time itself. The term granite appears to be a corruption of the Latin word *geranites*, used by Pliny to denote a particular species of stone. Tournefort, the naturalist, in the *Account of his Voyage to the Levant* in 1699, is the first of modern writers who uses the name. The word seems to have been applied by antiquaries to every granular stone susceptible of use in architecture or sculpture, in which vague sense it was used by mineralogists, until about fifty years since, when true granite was classed as a particular mountain rock. Its constituent parts are concretions of felspar, quartz, and mica, intimately joined together, but without any basis or ground. These parts are variable in quantity, so that sometimes one, sometimes the other, and frequently two of them, predominate over the third. The felspar, however, generally predominates, as mica is the least considerable ingredient of the rock. In some varieties the quartz is wanting, in others the mica; but where these peculiarities occur, the granites must be considered as varieties, not as distinct species.

1669. The constituent parts differ in their magnitude, alternating from large to small and very fine granular. The colour, moreover, is very variable, depending principally on the predominating ingredient, — the felspar, the quartz, and the mica having usually a grey colour. The felspar is mostly white, inclining to grey and yellow, sometimes red, and even also milk white, sometimes flesh-red; rarely grey, yellow, or green. The quartz is usually grey, seldom milk-white, and always translucent. The mica is usually grey, and sometimes nearly black. The felspar in granite has usually a vitreous lustre, and of perfectly foliated fracture; yet in some varieties it passes into earthy, with the loss of its hardness and lustre; in other words, it has passed into porcelain earth. The appearance in question is sometimes produced by the weathering of the felspar, and sometimes it appears to be in its original state. When pyrites are found in the veins which traverse granite, the vicinous felspar and mica are converted into a species of steatitical matter by the action of the sulphuric acid formed during the decomposition of the pyrites. The mica also is liable to decomposition from exposure to the atmosphere, but the quartz never alters. In Cornwall, there is a considerable portion of the granite in which earthy felspar is found.

1670. Granite is not decomposed by acids, and is only imperfectly and slowly calcinable in a great heat. Those species which contain much white felspar, and only a small portion of quartz, like the greater part of the granites of Cornwall and Devonshire, are liable to decomposition much sooner than many of the Scotch granites, in which the quartz is more abundant, and equally disseminated. In the selection of the Cornish and Devon granites, those are to be preferred which are raised in the largest blocks and are easiest worked, which, for common purposes, answer well enough, such as for paving-stones and the like; but harder granite must be sought for than Devonshire or Cornwall produces, where the construction is of importance; for the masses in these counties are mostly in a condition of rapid disintegration and decay, which seems chiefly attributable to their containing a large portion of potass. The Naval Hospital of Plymouth is built of a granite whose parts appear to have been well selected. It was erected upwards of seventy years since, and, except in the columns of the colonnades, does not exhibit symptoms of decay. In these, on their more exposed sides, the disintegration of the felspar has commenced, and lichens have already attached their roots to some parts of the surfaces.

1671. The grey granite, or moorstone as it is called in Cornwall, is got out in blocks by splitting it with a number of wedges applied to notches *pooled* in the surface of the stone about four inches apart. The *pool holes* are sunk with the point of a *pick*, much in the same way as other hard quarry stones are split. The harder the moorstone the nearer it can be split to the scantling required. All granite may be wrought, and, indeed, is wrought into mouldings by means of pointed tools of various weights and sizes; but it is first roughed out by means of heavy hammers, whose shape is formed by two acute angled triangles, joined base to base by a rectangle between them, thus . Red granite, sometimes yellowish, and generally interspersed with black mica, is found in Devonshire, and indeed at Mount Edgcumbe there are fine tables of it equal to the finest oriental granite, and it is found also in other parts of England; but for hardness, and in works where durability is indispensable, the granite from Aberdeen and Dundee is to be preferred by the architect. These take an admirable polish, and are superior to all others which the island produces. Of these the red generally is harder than the grey sorts, but more difficult to work. The Peterhead, from the vicinity of Aberdeen, is perhaps the best, and it is, moreover, in appearance, the most beautiful which Scotland affords; indeed, in point of beauty, it is only surpassed by the oriental granites.

1672. The common granite is the material chiefly used for paving the roads of the metropolis.

A cubic foot of Aberdeen grey granite weighs		166⅓ lbs.
Aberdeen red granite	-	165¼
Cornish grey granite	-	166¾
Cornish red granite	-	164

Sect. III.

MARBLE.

1673. With the architect and sculptor the name of marble is applied to all stones, harder than gypsum, which are found in large masses, and are susceptible of a good polish. On this principle, under the head of marble, are included many varieties of limestone, porphyry, and even granite and fine-grained basalts. But with mineralogists the word is used in a much more restricted sense, and is confined to such varieties of dolomite, swinestone, and compact and granularly foliated limestone as are capable of receiving a good polish.

1674. The *external characters* are as follows: colours white, grey, red, yellow, and green. Has generally but one colour, though it is often spotted, dotted, striped, and veined. Occurs massive, and in angulo-granular distinct concretions. Internally it alternates from shining to glistening and glimmering; lustre intermediate between pearly and vitreous. Fracture foliated, but oftentimes inclining to splintery. Fragments indeterminate, angular, and rather blunt-edged. More or less translucent. Brittle, and easily frangible. Its *chemical characters* are, that it generally phosphoresces when pounded, or when thrown on glowing coals. It is infusible before the blow-pipe. Dissolves with effervescence in acids.

Constituent parts,	Lime - - -	56·50
	Carbonic acid - -	43·00
	Water - - -	0·50
		100·00

1675. All the varieties may be burnt into quicklime; but it is found that in many of them the concretions exfoliate and separate during the volatilization of their carbonic acid, so that by the time that they become perfectly caustic, their cohesion is destroyed, and they fall into a kind of sand, a circumstance which renders it improper to use such varieties in a common kiln. The most important use, however, of marble is as a material for decoration.

1676. The varieties of marble are almost infinite, and their classification would be perhaps useless here. Among those in use with the ancients, the white marble of mount Penteles in Attica, thence called *Pentelican*, seems to have held the first rank. It was used in the Parthenon and other buildings in Athens, and was also in high repute with the Greek sculptors. The *Parian* marble of the finest description was obtained from Mount Marpessus in the island of Paros, whence it was also called *Marpessian* marble. This sort was also highly esteemed. The Parian marble was sometimes termed *Lychneus*, from its employment for candelabra, and *Lygdinum*, from the promontory of Lygdos. Another marble of antiquity was that from Mount Hymettus in Attica. Thasus and Lesbos produced white marbles, much esteemed; and the latter also a marble of a black colour. But a marble whiter than even that of Paros was found at Luna in Etruria. Amongst the white marbles also was the *Marmor Phellense* from Mount Phelleus; *Coraliticum*, from the neighbourhood of the river Coralios in Phrygia, termed also *Sangarium*, from a different name of the same river; and the *Cyzicum*, from the quarries of Cyzicus in Asia Minor. The *Chernites* resembled ivory in its colour. Among the black marbles were the *Synnadicum*, or *Phrygium*, from the vicinity of the city of Synnada in Phrygia; that of *Tænarus*, the Marmor *Libicum*, or *Numidian*, also called *Luculleum*, called by the French *noir antique* or *rouge antique*. Of a transparent black colour also was the celebrated *Chium Marmor*, from Mount Pelineus in the island of Chios. The *Marmor Obsidianum*, from Ethiopia, was also black. Of the same colour, but veined, was that from the isle of Proconesus, called *Proconesian* or *Cyzican* marble. Mount Taygetes produced the *Marmor Laconicum*, of a green colour, more generally now known by the name of *verd antique*. That of *Carystus* was of a mingled green. The *Atraicum Marmor*, from Mount Atrax in Thessaly, was a mixture of white, green, blue, and black. The *Tiberian* and *Augustan* marbles were from Egypt, and of a green colour. That of a dark green, which is called *serpentino antico*, from the alleged resemblance of its colour to the skin of a serpent, was anciently called *Marmor Aphites* or *Memphites*, and was obtained, as its second name imports, from the neighbourhood of Memphis. The *Corinthian* was a yellow marble; the *Phingites*, from Cappadocia, white with yellow spots. The *Rhodian* was marked with spots of a golden appearance; and that of *Melos*, obtained from Mount Acynthus, was also yellow.

1677. The Parian marble, above mentioned, consists almost entirely of carbonate of lime; that of Carrara, in Italy, is often mixed with granular quartz in considerable proportion. Dr. Clarke says that while the works in Parian marble remain perfect, those in Pentelic marble have become decomposed, and sometimes exhibit a surface as earthy and rude as that of common limestone. This is considered to be principally owing to veins of extraneous substances which intersect the Pentelic quarries, and which appear more or less in all the works executed in this kind of stone. The Parian marble has a waxy appearance when polished; it hardens by exposure to the air, and must be held in estimation even now, as the material from which were formed the Venus di Medici, the Diana Venatrix, the colossal Minerva Pallas of Velletri, and the Capitoline Juno. The marbles known by the names of Verde antico and Verde di Corsica are composed of limestone, calcareous spar, serpentine, and asbestus.

1678. The marbles of France are many of them extremely beautiful, but their use is chiefly confined to that country.

1679. The marbles of the British Islands deserve more notice from the English architect than they have hitherto received. In England there are but few as yet quarried of granular foliated limestone, the greater number of varieties of them belonging to the flœtz or secondary limestone. Derbyshire and Devonshire abound with marble; but the most remarkable, and perhaps most beautiful, of the English marbles, is that of Anglesea, called *Mona marble*, and much resembling Verd antique. Its colours are greenish black, leek green, and sometimes purple, irregularly blended with white, but they are not always seen together in the same piece. The white part is limestone, the green shades are said to be owing to serpentine and asbestus. The black marbles found in England are varieties of lucullite.

1680. Of the Scotch marbles the principal are the *Tiree*, of which there are two varieties, red and white. The *Iona*, whose colours are a greyish white and snow white, sometimes intermixed with steatite, which gives it a green or yellow colour in spots known under the name of Iona or Icolmkill pebbles. It does not take a high polish. The *Skye* marble, of greyish hue, with occasionally various veins. The *Assynt* varieties of white, of grey, and dove colour. *Glen Tilt* marble, white and grey, with occasionally yellow and green spots. Marble of *Balliculish*, of a grey or white colour, and capable of being produced in considerable blocks. *Boyne* marble, grey or white, and taking a good polish. *Blairgowrie*, in Perthshire, of a pure white colour, fit, it is said, to be employed in statuary and for architectural purposes; and *Glenavon*, a white marble, said by Williams (*Natural History of the Mineral Kingdom*) to be a valuable marble, is not used, from the remoteness of its situation and the difficulty of access to it.

1681. The black marbles of Ireland, which have of late been much introduced for architectural purposes, are lucullites. In the county of Waterford are several kinds. At Toreen is a fine variegated sort of various colours, viz., chesnut brown, white, yellow, and blue, and taking a good polish. A grey marble, beautifully clouded with white, and susceptible of a good polish, has been found near Kilcrump, in the parish of Whitechurch, in the same county. At Loughlougher, in the county of Tipperary, a fine purple marble is found, which is said to be beautiful when polished. Several variegated marbles are described by Smith in the county of Cork, but it does not appear certain whether these and others are granular limestone. The county of Kerry affords several variegated marbles, such as that found near Tralee. Marble of various colours is found in the same county, in the islands near Dunkerron, in the river of Kenmare: some are purple and white, intermixed with yellow spots; and some beautiful specimens have been seen of a purple colour, veined with dark green.

1682. The principal part of the supply to England of foreign marble is from Carrara, a small Italian town in the duchy of Massa. The quarries at this place were celebrated from an early period, and spots are still shown about them whence they dug the marble for the Pantheon. Masses of marble are sometimes procured here nine feet in length and from four to six in breadth. The marble produced besides the white statuary is of different colours and veins. The quarries are the property of the principal inhabitants of the town, who carry on an extensive trade in the article; but the difficulty of choosing the marble has induced artists to settle there for the execution of their works, and the consequence is, that sculpture abounds and flourishes in the town.

1683. There is a beautiful species of yellow marble obtained from the quarries near Siena, but the quantity imported is not very great.

Sect. IV.

TIMBER.

1684. The information we propose here to lay before the reader relative to the different species of timber is extracted from Miller's *Gardener's Dictionary*, Rondelet's *Art de Bâtir*, *Rees's Cyclopædia*, and Hunter's edition of Evelyn's *Sylva*. To give any thing like the information that would satisfy the botanist would be out of place in an architectural work; and we therefore confine our observations to those which will be useful to the student.

1685. Oak. Of this most valuable timber for building purposes Vitruvius (lib. ii. cap. ix.) enumerates five species, which it would now be difficult to identify. That some species of the Quercus of the botanists are more valuable for building purposes than others no doubts exist. Evelyn seems to commend especially the Irish oak, because of its withstanding the efforts of the worm; but it is not easy to ascertain the particular species to which he alludes. In the present day the Sussex oak is esteemed the most valuable; a value, according to some authors, derived from the nature of the soil and from good management in the culture, which is an object of no small importance.

1686. Generally, it has been usual to consider England as producing, without difference in quality, but one species of oak; but two sorts are well known to the English botanist, the *Quercus Robur* and the *Quercus jessiflora*. The former is found throughout the temperate parts of Europe, and is that most common in the southern parts of England. Its leaves are formed with irregular sinuosities, and their footstalks are short, occasionally almost without any at all. It attains a very large size, and the wood is tolerably straight-grained and pretty free from knots, in many instances resembling the German species called wainscot. It is easily split for making laths for plasterers and slaters, and is beyond doubt the best sort for joists, rafters, and other purposes where stiff and straight-grained timber is a desideratum. In the Quercus jessiflora, which, though found about Dulwich and Norwood, according to Miller, appears to be the common oak of Durham, and perhaps of the north of England, the leaves have long footstalks, frequently an inch in length, and their sinuosities are not so deep, but are more regular than those of the Robur just described. The acorns are so close to the branches as to have scarcely any stalks. The wood is of a darker hue, and the grain is so smooth that it resembles chesnut. Than the Robur it possesses more elasticity, hardness, and weight, but in seasoning it is subject to warp and split; hence unfit for laths, which in the north of England are rarely of oak. There is no reason for supposing, as has been conjectured, that the oak of the Gothic roofs of the country is of this species, though we are aware of the great durability of the oak in the buildings in the northern part of the island.

1687. The specific gravity of the species first named, that is, the Quercus Robur, may be taken at about ·800, and the weight of a cube foot 50·45 lbs. That of the last-named at ·875, and the weight of a cube foot at about 55·00 lbs. Their cohesive force and toughness are proportionable.

1688. The American species scarcely claim a notice here, because their use in England is, from every circumstance, out of the question. Of the red oak of Canada (Quercus rubra), the only one of which the use could be contemplated, we merely observe, that it is a light, spongy, and far from durable wood, though, in the country, in many instances useful. Its growth is rapid, and it rises to the height of 90 or 100 feet.

1689. There is a species of oak imported from Norway, which has received the name of *clapboard*, and another imported from Holland, known under the name of *Dutch wainscot*, though grown in Germany, whence it is floated down the Rhine for exportation. The latter is destitute of the white streaks which cross the former, and is thereby distinguished from it. The use of these woods has latterly much diminished in England. They are both softer than common oak, and the clapboard far inferior to wainscot. They are more commonly used for fittings and fixtures, whereto they are well adapted. In damp situations, oak decays gradually from its external surface to the centre of the tree; the ring on the outside, which it acquired in the last year of the growth of the tree, decaying first; but if the tree be not felled till past its prime, its decay is reversed by its commencement at the centre. An oak rarely reaches its prime under the age of an hundred years; after that period, which is that of its greatest strength, it cannot be considered as fit for building purposes; and, indeed, it may be taken as a rule, that oak before arriving at its maturity is stronger than that which has passed it.

1690. If the architect has the opportunity of selecting the timber whilst in a state of growth, he will, of course, choose healthy, vigorous, and flourishing trees. Those in which the trunks are most even are to be preferred. A mark of decay is detected in any swelling above the general surface of the wood. Dead branches, especially at the top of the tree, render it suspicious, though the root is the best index to its soundness. The notion of Alberti (*De Re Ædificatoria*), of using all the timber in the same building from the same forest, is a little too fanciful for these days, though we confess we have some misgivings in impugning an authority which, in most other respects, we are inclined to receive with the highest veneration.

1691. In felling not only the oak, but all other large trees, the great branches should be first cut off, so that the tree may not be injured or strained in its fall; and the trunk, moreover, must be sawed as close to the ground as possible. When felled, but not before, it is to be barked, trimmed of its branches, and left to season. Before, however, leaving it for this purpose, it is considered by workmen better to square it, which, it is thought, prevents its tendency to split. If to be employed for posts or bearing pieces, boring it has been employed with success; but it is needless to observe, that in pieces subject to transverse strains such a practice is not to be spoken of.

1692. The pieces selected for building must be chosen with the straightest grain; but there are pieces which are occasionally employed, as for knees and braces, wherein a curvilinear direction of the fibres of the timber is extremely desirable. It may, however, be generally stated, that, in the case of two equal-sized and seasoned pieces, the heavier is the piece to be preferred.

1693. In oak, as in all other woods, the boughs and branches are never so good as the body of the tree; the great are stronger than the small limbs, and the wood of the heart stronger than all. When green, wood is not so strong as when thoroughly dry, which it rarely is till two or three years after it is felled. It is scarcely necessary to say, that, containing much sap, it is not only weaker, but decays sooner. It is weakened by knots, at which, in practice, it is found that fractures most frequently occur; and it is important to the architect to recollect that he should always reject cross-grained pieces.

1694. The great use of oak in this country is more for ship-building purposes than for architectural, its use, except in the provinces, being principally confined to pieces which are much liable to compression, or where great stiffness is required, or in pieces like sills to windows and door-cases, where there is much alternation of dryness and damp. So early as 1788, the consumption of oak for ship-building purposes was, in that year, upwards of 50,000 loads.

1695. When of good quality, it is more durable than any other wood which is procurable of a like size. In a dry state, it is ascertained to have lasted nearly a thousand years. The open-fibred porous oak of Lincolnshire, and some other places, is a bad sort. The best is that with the closest grain and the smallest pores. The colour, as is well known, is a fine brown; that which partakes of a reddish hue is not so good as the other. The smell of it is peculiar; it contains gallic acid, and it assumes a black purple colour when damp, by contact with iron. It warps and twists much in seasoning, and shrinks in width about one thirty-seventh part.

1696. **CHESNUT.** One of the finest of the European timber trees, the *Fagus castanea* of botanists, was heretofore so common in this country, that Fitzstephen, in his description of London about the time of Henry II., mentions a fine forest of chesnuts as growing on the northern side of the city. We know that it was much used in the buildings of our ancestors, and was, perhaps, even the chief timber employed. The young tree vies with the oak in durability, from the small proportion of sapwood it contains. Of its durability, the roofs of Westminster Hall, that of King's College, Cambridge, and that of Notre Dame, at Paris, are cited as examples, though the fact of the latter being of chesnut is doubted by Rondelet, who says that Buffon and D'Aubenton thought it a species of oak, which may be the case in the roof first named.

1697. Chesnut, however, is not to be trusted as is oak. As Evelyn observed, it is often well-looking outside, when decayed and rotten within. Belidor says it soon rots when the ends of timbers of it are closed round in a wall.

1698. It is, perhaps, from the circumstance of its colour so nearly resembling that of oak, that one timber has so often been mistaken for the other. The difference, however, is, that the pores of the sapwood of the oak are larger and more thickly set and easily distinguished, whilst those in the chesnut require magnifying powers to be distinguished. But a more decided difference is, that the chesnut has no large transverse septa. It is far easier to work than oak, and is not very susceptible of swelling and shrinkage. From what has been mentioned above, it may be inferred that the wood, though tough and compact, is, when young, hardest and most flexible, the old wood being often shaky and brittle.

1699. Water pipes of this tree endure much longer than those of elm; and for tubs and vessels to hold water, it is superior to oak; for when once thoroughly seasoned, it will neither shrink nor swell, on which account it is used by the Italians for wine tuns and casks. It will thrive on most soils, but rather delights in a rich loamy land, succeeding well, also, on that which is gravelly, clayey, or sandy. Mixed soils are suitable to it, and it is found in the warmer mountainous situations of most parts of Europe.

1700. From the experiments, the cohesive force of a square inch of chesnut, when dry, varies from 9570 to 12000 lbs., and the weight of a cubic foot, when dry, is from 43 to 55 lbs.

1701. Beech (*Fagus Sylvatica*). A beautiful tree, growing to a considerable height, and carrying a proportionable trunk. It flourishes most in a dry warm soil, and grows moderately quick. The wood is hard, close, has a dry even grain, and, like the elm, bears the drift of spikes. The sorts of beech are the brown or black, and the white beech. It is common throughout Europe. In the southern parts of Buckinghamshire, where the soil is chalky, it is particularly abundant; and such is the case near Walberton, in Sussex, on the southern range of chalk hills, where the beeches are very fine.

1702. Constantly immersed in water, the beech is very durable; such also is the case with it when constantly dry; but mere damp is injurious to it, and it is very liable to injury by worms, though to these Duhamel considers it much less liable when water-seasoned, than when seasoned in the common way. To render it less liable to the worm, it has been recommended to fell it about a fortnight after Midsummer, to cut it immediately into planks, which are to be placed in water about ten days and then dried. Beech is little used in building, except for piles, in which situation, if constantly wet, they are very durable. From its uniform texture and hardness, it is a good material for tools and furniture, and of it, in boards and planks, large quantities are brought to London. It is without sensible taste and smell, easy to work, and susceptible of a very smooth surface. The white sort is the hardest, though the black is tougher, and, according to Evelyn, more durable. The weight of a cube foot varies from 43 to 53 pounds.

1703. Walnut (*Juglans, quasi Jovis glans*) is of several sorts. The Juglans Regia, or common walnut, was formerly much cultivated in this island, as well for the sake of its timber as of its fruit. On the former account the importation of mahogany has long since rendered its cultivation less common. It flourishes better in a thin limestone soil, than in one that is rich and deep, and, if raised for timber, should not be transplanted, but remain in the place where it is sown. For furniture, from its rich brown colour, it is by many persons preferred to mahogany. Its scarcity renders its employment rare for building purposes, though by the ancients it was so employed. One of its properties is, that it is less liable to be affected by worms than any other timber, cedar only excepted; but from its brittle and cross-grained texture, it is not generally useful for the main timbers of a building.

1704. The heart-wood is of a greyish brown with dark brown pores, often veined with darker shades of the same colour, which are much heightened by oiling. The texture is not so uniform as that of mahogany, nor does it work so easily, but it may be brought to a smoother surface. The weight of a cubic foot is about 45 pounds.

1705. Cedar (*Pinus Cedrus*) is an evergreen cone-bearing tree, of which though several have been grown in this country, it is too scarce to be employed in building. Its durability is very great; such, indeed, that Pliny states cedar to have been found in the Temple of Apollo at Utica, which must have been 1200 years old. Its colour is a light rich yellow brown, with the annual rings distinct. It is resinous, and has a powerful smell. The taste is slightly bitter, and it is not subject to worms. It is very straight in the grain, works easily and splits readily. Weight of a cubic foot from 30 to 38 pounds.

1706. Fir (*Pinus Sylvestris*). The red or yellow fir is produced on the hills of Scotland; but the forests of Russia, Denmark, Norway, Lapland, and Sweden produce the finest timber of this species. It is imported, under the name of red wood, in *logs* and *deals*. From Norway the trees are never more than 18 inches diameter, whence there is much sap-wood in them; but the heart is a stronger and more durable wood than is had from larger trees of other countries. From Riga a great deal of timber is received under the name of *masts* and *spars:* the former are usually 70 or 80 feet in length, and from 18 to 25 inches diameter; when of less diameter they take the latter name. Yellow deals and planks are imported from Stockholm, Frederickshall, Christiana, and various other parts of Sweden, Russia, Norway, and Prussia. Of the pine species the red or yellow fir is the most durable; and it was said by the celebrated Brindley, that red Riga deal, or pine wood, would endure as long as oak in all situations. In Pontey's *Forest Pruner*, on the authority of Dr. Smith, an instance is given of the durability of natural-grown Scotch fir. It is therein stated, that some was known to have been 300 years in the roof of an old castle, and that it was as fresh and full of sap as timber newly imported from Memel, and that part of it was actually wrought up into new furniture. It is to be observed, that foreign timber has an advantage too seldom allowed to that which is grown at home, the former being always in some degree seasoned before it arrives in this country, and therefore never used in so unseasoned a state as the latter timber usually is.

1707. From its great lightness and stiffness it is superior to any other material for beams, girders, joists, rafters, and framing in general. In naval architecture it is used for masts and various other parts of vessels. In joinery, both internal and external, it stands better, is nearly as durable as oak, and is much cheaper.

1708. There is great variety in the colours of the different sorts of this fir: it is generally of a red or honey yellow of different degrees of brightness, and consists in section of hard and soft circles alternately, one part of each annual ring being soft and light coloured, the other harder and dark coloured, and possessing a strong resinous taste and smell. When not abounding in resin it works easily. That from abroad shrinks in the log, from seasoning, about one thirtieth part of its width.

1709. The annual rings of the best sort of this timber do not exceed one tenth of an inch in thickness, their dark parts are of a bright red colour. That from Norway is the finest of the sort, to which the best Riga and Memel are much inferior. The inferior timber of this kind, which is not so durable nor so capable of bearing strains, has thick annual rings, and abounds with a soft resinous matter, which is clammy and chokes the saw. Much of the timber of this sort is from Sweden, but it is inferior in strength and stiffness. That which is produced in the colder climates is superior to that which is the product of warmer countries, the Norway timber being much harder than that of Riga. The weight of a cubic foot of this fir, when seasoned, varies from 29 to 40 pounds. That of English growth, seasoned, from 28 to 33.

1710. WHITE FIR (*Pinus abies*), commonly called the spruce of Norway, whose forests produce it in abundance. This is the sort which in deals and planks is imported from Christiana, in which condition it is more esteemed than any other sort. The trees from which these are generally obtained are of 70 or 80 years' growth, and are usually cut into three lengths of about 12 feet each, which are sawn into deals and planks, each length yielding three deals or planks. Their most usual thickness is 3 inches, and they are generally 9 inches wide. In this country they are sold by the hundred, which in the case of white as well as yellow deals, contains 120 deals, be their thickness what it may, reduced to a standard one of an inch and a half, a width of 11 inches, and a length of 12 feet. What is called whole deal is an inch and a quarter thick, and slit deal is one half of that thickness. It unites better by means of glue than the yellow sort, is used much for interior work in joinery, and is very durable when in a dry state.

1711. The colour of the spruce fir is a yellow or rather brown white, the annual ring consisting of two parts, one hard, the other softer. The knots are tough, but it is not difficult to work. Besides the importation above named, there is a considerable quantity received from America. Of the Christiana fir a cubic foot weighs from 28 to 32 pounds when seasoned. That from America about 29 pounds; and the Norway spruce grown in Britain about 34 pounds. In seasoning it shrinks about a seventieth part, and after being purchased as dry deals at the timber yards, about one ninetieth.

1712. AMERICAN PINES. The *Pinus Strobus*, or what is called the Weymouth or white pine, is a native of North America, imported in logs often more than 2 feet square and upwards of 30 feet in length. It is an useful timber, light and soft, stands the weather tolerably well, and is much used for masts. For joiners' work it is useful from its clean straight grain. But it should not be used for large timbers, inasmuch as it is not durable, and is moreover very susceptible of the dry rot. Its colour is a brown yellow, and it has a peculiar odour. The texture is very uniform, more so, indeed, than any other of the pine species, and the annual rings are not very distinct. It stands well enough when well seasoned. A cubic foot of it weighs about 29 pounds.

1713. The yellow pine, or *Pinus variabilis*, is imported into England, but it is not much used; it is the produce of the pine forests from New England to Georgia.

1714. The pitch pine (*resinosa*), remarkable for the quantity and fragrance of the resin it produces, is a native of Canada. It is brittle when dry, and, though heavy, not durable. It is of a much redder hue than the Scotch pine, and from its glutinous property difficult to plane. The weight of a cubic foot is 41 pounds.

1715. The silver pine (*picea*) is common in the British plantations. This species of timber is produced in abundance, and is much used on the Continent both for carpentry and ship-building. It is light and stiff, and, according to Wiebeking, lasts longer in air than in water. A cubic foot weighs about 26 pounds.

1716. The Chester pine (*pinaster*) is occasionally cultivated in the British plantations. It is better suited to water than exposure to the air, and has a finer grain, but contains less resin, than the pine or silver fir. A cubic foot weighs about 26 pounds.

1717. LARCH (*Pinus Larix*). A timber tree only lately to any considerable extent adopted in the plantations of Great Britain, among whose cultivators the Duke of Athol has been one of the most ardent and successful. It grows straight and rapidly, is said to be durable in all situations, and appears to have been known and appreciated by Vitruvius, who regretted the difficulty of its transport to Rome, where, however, it was occasionally used. Wiebeking prefers it to the pine, pinaster, and fir, for the arches of timber bridges. To flooring boards and stairs, where there is much wear, it is well suited, and when oiled, assumes a beautiful colour, such, indeed, that when used for internal joinery, a coat of varnish gives it a more beautiful appearance than it could receive from any painting. The American larches do not produce turpentine; but the timber has been considered equal to the European sorts. It is of a honey yellow colour, and more difficult to work than the Riga or Memel timber, though, when obtained, the surface is better. It bears the driving to nails and bolts, and stands well if properly seasoned. A cubic foot weighs from 30 of 40 pounds.

1718. Poplar. The *Populus* of botanists, whereof five species are grown in England: the common white poplar, the black, the aspen or trembling poplar, the abele or great white poplar, and that of Lombardy. The wood of this tree is only fit for the flooring of inferior rooms where there is not much wear. Evelyn attributes to this wood the property of burning "*untowardly*," rather mouldering than maintaining any solid heat. Its colour is a yellow or brown white. The annual rings, whereof one side is a little darker than the other, making each year's growth visible, are of an uniform texture. The best sorts are the Lombardy, the black, and the common white poplar. Of the Lombardy poplar, the weight of a cubic foot is about 24 pounds; of the aspen and black poplar, 26 pounds; and of the white poplar, about 33 pounds.

1719. Alder (*Betula alnus*). A tree delighting in wet places by the banks of rivers, and whereof, says Vitruvius, the piles whereon the whole of the buildings of Ravenna stand, furnished the material. In a dry situation it is unfit for employment, on account of its early rot when exposed to the weather or to mere damp, and its susceptibility of engendering worms. Evelyn says that it was used for the piles upon which the celebrated bridge of the Rialto at Venice was founded in 1591; but we have no certain data by which such assertion can be maintained. There is, however, no doubt that it may be advantageously employed in situations where it is constantly under water.

Its colour is of a red yellow, of different shades, but nearly uniform; which latter quality is exhibited in its texture.

From its softness it is easily worked, and seems adapted, therefore, for carving. In a dry state the weight of a cubic foot varies from 36 to 50 pounds.

1720. Elm (*Ulmus*). In Great Britain five species of this tree abound, whereof the *Ulmus campestris*, common in the woods and hedges of the southern parts of England, is a hard and durable wood, but is rarely used except for coffins. The *Ulmus suberosa*, or cork-barked elm, is an inferior sort, and is very common in Sussex.

1721. The *Ulmus Montana* is the most common species in Europe, and particularly in the northern counties of England. It is more generally known by the name of the broad-leaved elm or wych hazel. Without enumerating the other varieties, whereof the Dutch elm (*Ulmus major*) is good for nothing, we shall merely observe, that the *Ulmus glabra*, common in Herefordshire, Essex, and the north and north-eastern counties of England, grows to the largest size and is most esteemed, whilst the Dutch elm is the worst. The elm is a durable timber when constantly wet, as a proof whereof we have only to mention that it was used for the piles on which the old London Bridge stood. Indeed, its durability under water is well known; but for the general purposes of building it is of little value, and it rarely falls to the lot of the architect to be obliged to use it.

1722. The colour of the heart-wood is darker than that of oak, and of a redder brown. The sapwood is of yellow or brown-white colour. It is porous, cross and coarse grained, has a peculiar smell, twists and warps very much in drying, and shrinks considerably in breadth and length. Though difficult to work, it bears the driving of bolts and nails better than most other sorts of timber. The weight of a cubic foot, when dry, varies from 36 to 48, seasoned from 37 to 50 pounds. From experiment it seems that in seasoning it shrinks one forty-fourth part of its width.

1723. Ash (*Fraxinus excelsior*). This, the most valuable of the genus, is common throughout Europe and the northern parts of Asia. It grows rapidly, and of it the young is more valuable than the old wood. It is much affected by the difference of the soils in which it grows. It will not endure when subject to alternations of damp and moisture, though sufficiently durable when constantly in a dry situation. Its pores, if cut in the spring, are of a reddish colour, and it is improved by water-seasoning. Evelyn says, that when felled in full sap, the worm soon takes to it; and therefore recommends its being felled in the months from November to February. The texture is compact and porous, the compact side of the annual ring being dark in colour, whence the annual rings are distinct. The general colour is brown, resembling that of oak; but it is more veined, and the veins darker than those of oak. The timber of the young tree is a white, approaching brown, with a greenish hue. It has no peculiar taste or smell, is difficult to work, and is too flexible for use in building, beside the important want of the character of durability. The weight of a cubic foot varies from 35 to 52 pounds; and it is to be observed, when the weight is much less than 45 pounds the timber is that of an old tree.

1724. Sycamore (*Acer pseudo-platanus*), usually called the plane tree in the northern part of the island, is common in Britain and on the mountains of Germany. It is rapid in growth, and the wood is durable when it escapes the worm, to which it is quite as liable as beech. The use of it in buildings is not common, but for furniture it is valuable. The colour is a brown white, yellowish, and sometimes inclining to white. Texture uniform; annual rings indistinct. It is not so hard as beech, brittle, and generally easy to work. A cubic foot, when seasoned, weighs from 34 to 42 pounds. Ware says that there are old houses in this country floored with sycamore and wainscotted with poplar. It seems well enough calculated for floors.

1725. BIRCH. *Betula alba*, or common birch, is a species of alder, to which article the reader is referred. (1719.)

1726. MAHOGANY (*Mahagoni*) has only three known species. That used (*Swietenia*) in England is a native of the West Indies, and the country round the Bay of Honduras in America. It was formerly abundant in the low lands of Jamaica, but is only found there, at present, on high hills and places difficult of access. It succeeds in most soils, though it varies in quality according to their natures. In rocky situations, though it does not attain so great a size, it is harder, weightier, of a closer grain, and more beautifully variegated than in low rich lands, whereon it is produced more porous, of paler colour, and of more open grain. It grows straight and lofty, and when full grown reaches a diameter of 5 feet. The flowers are of a red or saffron colour, and the fruit about the size of a turkey's egg. The wood is extremely hard, takes a fine polish, and is admirably adapted to articles of furniture. The expense of it in this country confines its use in building to doors, handrails of stairs, &c.; but in Jamaica it has been frequently used for floors, joists, rafters, shingles, &c.; and, indeed, ships have been built of it; for which last purpose, the circumstance of its allowing the shot to be buried without splintering makes it peculiarly suitable.

1727. The first use to which it was applied in this country was by a Mr. Wollaston to the ignoble service of a candle-box for a Dr. Gibbons, at the beginning of the last century (1724). With its appearance the doctor was so much pleased that he had a bureau afterwards made of it.

1728. The variety called Spanish mahogany, and imported from Cuba, Jamaica, Hispaniola, and other West India islands, comes in logs seldom more than 26 inches square, and about 10 or 12 feet in length, and is harder and closer grained than that from the Bay of Honduras, from which it may be distinguished, before it is oiled, by being of a lighter colour, and as if its pores were filled with a chalky matter. The Honduras mahogany has been latterly imported in logs of very large dimensions; we have ourselves seen one in the West India Docks which was 5 feet square, and upwards of 15 feet long. Its grain is very open generally, and often irregular, with black or grey spots. The veins are beautiful and of great variety. The best sort is that which is freest from grey specks and of a fine golden colour. It is held firmly with glue, perhaps, indeed, better than any other wood. A cubic foot of the best Jamaica mahogany weighs about 54 pounds; of Honduras, about 38 pounds.

1729. The teak and the African oak have latterly been imported into this country in considerable quantities. They are extremely hard and tough; but we do not, from the impossibility of their general use here, think it necessary to enter into any description of them. The following table, extracted from Rondelet's work, exhibits the mean heights of several sorts of trees, that of their trunks, their specific gravities and weight per cubic foot; in which latter column will be found some small differences from those already given, which may be accounted for from the variation in the qualities of the timber on which experiments were made.

Name of Tree.	Mean Height in English Feet.	Mean Height of Trunk in English Feet.	Diameter of Trunk in English Inches.	Specific Gravity.	Weight of Cubic Foot in lbs. averd.
Acacia	26·65	12·79	10·66	789	47·74
Alder	79·95	44·77	29·85	655	39·74
Almond tree	38·28	22·38	14·92	1102	66·74
Ash	63·96	38·37	23·45	787	47·52
Beech	76·72	44·77	27·72	720	43·63
Birch, common	86·34	47·97	31·98	702	42·55
Box	28·78	15·99	10·66	919	55·55
Cedar of Lebanon	95·94	51·16	39·44	608	36·50
Chataignier (wild chesnut)	76·72	44·77	27·71	685	41·47
Chesnut (sweet) Marronnier	76·72	44·77	27·71	720	43·73
Cypress (pyramidal)	76·72	38·37	27·71	655	39·74
Ebony of the Alps	31·98	19·18	11·73	1064	63·72
Elm	76·72	44·77	31·98	738	42·00
Fir	102·32	57·56	46·90	542	31·92
Linden	57·56	31·98	26·65	564	34·13
Oak (common of Canada)	95·94	57·56	35·18	842	51·18
Oak (red of Virginia)	86·34	47·97	31·98	587	35·42
Oak (common)	86·34	44·77	31·98	905	54·69

Name of Tree.	Mean Height in English Feet.	Mean Height of Trunk in English Feet.	Diameter of Trunk in English Inches.	Specific Gravity.	Weight of Cubic Foot in lbs. averd.
Pine (northern)	86·34	47·97	35·18	612	37·17
Plane	79·75	44·77	29·85	622	37·58
Poplar of Italy	79·95	47·97	31·98	415	24·25
Service tree (Cormier)	47·97	25·58	18·12	911	55·07
Sycamore	63·96	31·98	28·78	645	38·88
Walnut	57·56	47·97	36·24	680	41·04
Walnut (of America)	63·96	31·98	38·37	735	41·90
Yew	28·78	15·99	10·66	778	47·09

1730. The preservation of timber, the prevention of decay, and the causes of decay, will require from us a succinct notice; and we shall commence by placing before the reader the observations on the subject from the celebrated and venerated Evelyn, though perhaps at the risk of repetition in what follows. As King Henry V. is made by Shakspeare to say of Fluellen, "Though it appear a little out of fashion, there is much care in this" author.

1731. "Lay up your timbers very dry, in an airy place, yet out of the wind or sun, and not standing very upright, but lying along, one piece upon another, interposing some short blocks between them, to preserve them from a certain mouldiness which they usually contract while they sweat, and which frequently produces a kind of fungus, especially if there be any sappy parts remaining.

1732. "Some there are yet who keep their timber as moist as they can by submerging it in water, where they let it imbibe, to hinder the cleaving; and this is good in fir, both for the better stripping and seasoning; yea, not only in fir, but other timber. Lay, therefore, your boards a fortnight in the water (if running the better, as at some mill-pond head); and there, setting them upright in the sun and wind, so as it may freely pass through them (especially during the heats of summer, which is the time of finishing buildings), turn them daily; and thus treated, even newly sawn boards will floor far better than many years' dry seasoning, as they call it. But, to prevent all possible accidents, when you lay your floors, let the joints be shot, fitted, and tacked down only for the first year, nailing them for good and all the next; and by this means they will lie staunch, close, and without shrinking in the least, as if they were all one piece. And upon this occasion I am to add an observation, which may prove of no small use to builders, that if one take up deal boards that may have lain in the floor a hundred years, and shoot them [plane their edges] again, they will certainly shrink (*toties quoties*) without the former method. Amongst wheelwrights the water seasoning is of especial regard, and in such esteem amongst some, that I am assured the Venetians, for their provision in the arsenal, lay their oak some years in water before they employ it. Indeed, the Turks not only fell at all times of the year, without any regard to the season, but employ their timber green and unseasoned; so that though they have excellent oak, it decays in a short time, by this only neglect.

1733. "Elm felled ever so green, for sudden use, if plunged four or five days in water (especially salt water), obtains an admirable seasoning, and may immediately be used. I the oftener insist on this water seasoning, not only as a remedy against the worm, but for its efficacy against warping and distortions of timber, whether used within or exposed to the air. Some, again, commend burying in the earth; others in wheat; and there be seasonings of the fire, as for the scorching and hardening of piles, which are to stand either in the water or in the earth.

1734. "When wood is charred it becomes incorruptible; for which reason, when we wish to preserve piles from decay, they should be charred on their outside. Oak posts used in enclosures always decay about two inches above and below the surface. Charring that part would probably add several years to the duration of the wood, for that to most timber it contributes its duration. Thus do all the elements contribute to the art of seasoning.

1735. "Timber which is cleft is nothing so obnoxious to reft and cleave as what is hewn; nor that which is squared as what is round: and therefore, where use is to be made of huge and massy columns, let them be bored through from end to end. It is an excellent preservative from splitting, and not unphilosophical; though to cure the accident painter's putty is recommended; also the rubbing them over with a wax cloth is good; or before it be converted the smearing the timber over with cow-dung, which prevents the effects both of sun and air upon it, if of necessity it must lie exposed. But, besides the former remedies, I find this for the closing of the chops and clefts of green timber, to anoint and supple it with the fat of powdered beef broth [we do not quite agree with our author here], with which it must be well soaked, and the chasms filled with sponges dipped into it. This to be twice done over.

1736. "We spake before of squaring; and I would now recommend the quartering of such trees as will allow useful and competent scantlings to be of much more durableness and effect for strength, than where (as custom is and for want of observation) whole beams and timbers are applied in ships or houses, with slab and all about them, upon false suppositions of strength beyond these quarters.

1737. "Timber that you have occasion to lay in mortar, or which is in any part contiguous to lime, as doors, window cases, groundsils, and the extremities of beams, &c., have sometimes been capped with molten pitch, as a marvellous preserver of it from the burning and destructive effects of the lime; but it has since been found rather to heat and decay them, by hindering the transudation which those parts require; better supplied with loam, or strewings of brick-dust or pieces of boards; some leave a small hole for the air. But though lime be so destructive, whilst timber thus lies dry, it seems they mingle it with hair to keep the worm out of ships, which they sheathe for southern voyages, though it is held much to retard their course.

1738. "For all uses, that timber is esteemed the best which is the most ponderous, and which, lying long, makes the deepest impression in the earth, or in the water being floated; also what is without knots, yet firm and free from sap, which is that fatty, whiter, and softer part called by the ancients *albumum*, which you are diligently to hew away. My Lord Bacon (Exper. 658.) recommends for trial of a sound or knotty piece of timber, to cause one to speak at one of the extremes to his companion listening at the other; for if it be knotty, the sound, says he, will come abrupt."

PRESERVATION OF TIMBER.

1739. The preservation of timber, when employed in a building, is the first and most important consideration. Wherever it is exposed to the alternations of dryness and moisture, the protection of its surface from either of those actions is the principal object, or, in other words, the application of some substance or medium to it which is imperviable to moisture; but all timber should be perfectly dry before the use of the medium. In Holland the application of a mixture of pitch and tar, whereon are strewn pounded shells, with a mixture of sea sand, is general; and with this, or small and sifted beaten scales from a blacksmith's forge, to their drawbridges, sluices, and gates, and other works, they are admirably protected from the effects of the seasons. Semple, in his work on aquatic building, recommends, that "after your work is tried up, or even put together, lay it on the ground, with stones or bricks under it to about a foot high, and burn wood (which is the best firing for the purpose) under it, till you thoroughly heat, and even scorch it all over; then, whilst the wood is hot, rub it over plentifully with linseed oil and tar, in equal parts, and well boiled together, and let it be kept boiling while you are using it; and this will immediately strike and sink (if the wood be tolerably seasoned) one inch or more into the wood, close all the pores, and make it become exceeding hard and durable, either under or over water." Semple evidently supposes the wood to have been previously well seasoned.

1740. Chapman (on the preservation of timber) recommends a mixture of sub-sulphate of iron, which is obtained in the refuse of copperas pans, ground up with some cheap oil, and made sufficiently fluid with coal-tar oil, wherein pitch has been infused and mixed.

1741. For common purposes, what is called *sanding*, that is, the strewing upon the painting of timber, before the paint dries, particles of fine sand, is very useful in the preservation of timber.

1742. Against worms we believe nothing to be more efficacious than the saturation of timber with any of the oils; a process which destroys the insect if already in the wood, with that of turpentine especially, and prevents the liability to attack from it. Evelyn recommends nitric acid, that is, sulphur immersed in aquafortis and distilled, as an effectual application. Corrosive sublimate, lately introduced under Kyan's patent, has long been known as an effectual remedy against the worm. Its poisonous qualities of course destroy all animal life with which it comes in contact; and we believe that our readers who are interested in preserving the timbers of their dwellings may use a solution of it without infringing the rights of the patentee. But the best remedy against rot and worms is a thorough introduction of air to the timbers of a building, and their lying as dry and as free from moisture as practicable. Air holes from the outside should be applied as much as possible, and the ends of timbers should not, if it can be avoided, be bedded up close all round them. This practice is, moreover, advisable in another respect, that of being able, without injury to a building, to splice the ends of the timbers should they become decayed, without involving the rebuilding of the fabric; a facility of no mean consideration.

1743. The worm is so destructive to timber, both in and out of water, that we shall not apologise for closing this part of our observations with Smeaton's remarks upon a species of worm which he found in Bridlington piers. "This worm appears as a small white soft substance, much like a maggot; so small as not to be seen distinctly without a magnifying glass, and even then a distinction of its parts is not easily made out. It does not attempt to make its way through the wood longitudinally, or along the grain, as is the case with the common ship worm, but directly, or obliquely, inward. Neither does it appear to make its way by means of any hard tools or instruments, but rather by some species of dissolvent liquor furnished by the juices of the animal itself. The rate of progression is, that a three inch oak plank will be destroyed in eight years by action from the outside only." For resisting the effects of these worms, Smeaton recommends the piles to be squared, to be fitted as closely as possible together, and to fill all openings with tar and oakum, to make the face smooth, and cover it with sheathing.

1744. The destructive effects of the white ant are so little known here, that it is unnecessary to make further mention of them, than that in India they are the most inveterate enemies with which timber has to contend. From *Young's Annals* we extract the following curious statement of experiments made upon inch and a half planks, from trees of thirty to forty-five years' growth, after an exposure of ten years to the weather.

Cedar was perfectly sound.
Larch, sap quite decayed, but the heart, sound
Spruce fir, sound.
Silver fir, in decay.
Scotch fir, much decayed.
Pinaster, in a perfectly rotten state.

Chesnut, very sound.
Abele, sound.
Beech, ditto.
Walnut, decayed.
Sycamore, considerably decayed.
Birch, worthless.

Whence we may be led to some inference of the value of different sorts of timber in resisting weather; though we must not be altogether guided by the above table, inasmuch as it is well known that the soil on which timber is grown much increases or deteriorates its value, and that split timber is more durable and stronger than that which is sawn, from the circumstance of the fibres, on account of their continuity, resisting by means of their longitudinal strength; whereas when severed by the saw, the resistance depends more on the lateral cohesion of the fibres. Hence whole trees are invariably stronger than specimens, unless these be particularly well selected, and of a straight and even grain; but in practice the results of experiments are on this account the more useful.

DECAY OF TIMBER.

1745. If timber, whatever its species, be well seasoned, and be not exposed to alternate dryness and moisture, its durability is great, though from time it is known to lose its elastic and cohesive powers, and to become brittle if constantly dry. On this account it is unfit, after a certain period, to be subjected to variable strains: however, in a quiescent state it might endure for centuries. Dryness will, if carried to excess, produce this category. The mere moisture it absorbs from the air in dry weather is not sufficient to impair its durability. So, also, timber continually exposed to moisture is found to retain for a very long period its pristine strength. Heat with moisture is extremely injurious to it, and is in most cases productive of rot, whereof two kinds are the curse of the builder, the *wet* and the *dry* rot, though perhaps there be but little difference between the two. They appear to be produced by the same causes, excepting that the freedom of evaporation determines the former, and an imperfect evaporation the latter. In both cases the timber is affected by a fungus-like parasite, beginning with a species of mildew; but how this fungus is generated is still a *vexata quæstio;* all we know is, that its vegetation is so rapid, that often before it has arrived at its height, a building is ruined. From our inquiries on the Continent, we believe the disease does not occur to the extent that it does in this country; a fact which we are inclined, perhaps erroneously, to attribute to the use of the timber of the country, instead of imported timber. Our opinion may be fanciful, but there are many grounds on which we think that is not altogether the case. Our notion is, that our imported timber is infected with the seeds of decay long before its arrival here (we speak of fir more especially), and that the comparative warmth and moisture of the climate bring more effectually the causes of decay into action, especially where the situation is close and confined. Warmth is, doubtless, known to be a great agent in the dry rot, and most especially when moisture co-operates with it, for in warm cellars and other close and confined situations, where the vapour which feeds the disease is not altered by a constant change of air, the timbers are soon destroyed, and become perfectly decomposed.

1746. The lime, and more especially the damp brickwork, which receive the timbers of a new building, are great causes of decay to the ends of them; but we do not think that the regulations of the 19 Car. II. cap. 3., which directed the builders, after the fire of London, to bed the ends of their girders and joists in loam instead of mortar, would, if followed out in the present day, be at all effective in preventing the decay incident to the ends of timbers. Timber, in a perfectly dry state, does not appear to be injured by dry lime; and, indeed, lime is known to be effectual in the protection of wood against worms.

1747. Nothing is more injurious to the floors of a building than covering them with painted floorcloth, which entirely prevents the access of atmospheric air, whence the dampness of the boards never evaporates; and it is well known that oak and fir posts have been brought into premature decay by painting them before their moisture had evaporated; whilst in the timber and pewing of old churches, which have never been painted, we see them sound after the lapse of centuries. Semple, in his *Treatise on Building in Water*, notices an instance of some field gates made of the fir of the place, part whereof, near the mansion, were painted, and had become rotten, while those more distant from the mansion, which had never been painted, were quite sound.

PREVENTION OF DECAY.

1748. After timber is felled, the best method of preventing decay is the immediate removal of it to a dry situation, where it should be stacked in such a manner as to secure a free circulation of air round it, but without exposure to the sun and wind, and it should be rough squared as soon as possible. When thoroughly seasoned before cutting it into scantlings, it is less liable to warp and twist in drying. The ground about its place of deposit should be dry and perfectly drained, so that no vegetation may rise on it. Hence a timber yard should be strewed with ashes, or the scales from a foundry or forge, which supply an admirable antidote to all vegetation. It is thought that the more gradually timber is seasoned the greater its durability; and, as a general rule, it may be stated, that it should not be used till a period of at least two years from its being felled, and for joiners' work at least four years. Much, however, is dependent on the size of the pieces. By some, water seasoning has been recommended; by others, the steaming and boiling it; smoke-drying, charring, and scorching have also been recommended. The latter is, perhaps, the best for piles and other pieces that are to stand in the water or in the ground. It was practised by the ancients, and is still in use generally for the posts of park paling and the like.

1749. In Norway the deal planks are seasoned by laying them in salt water for three or four days, when newly sawed, and then drying them in the sun, a process which is considered to be attended with advantage; but it does not prevent their shrinking. Mr. Evelyn recommends the water seasoning for fir, but we incline to think that gradual dry seasoning is the best method.

1750. Notwithstanding, however, all care in seasoning, when timber is employed in a damp situation it soon decays; and one of the principal remedies against that is good drainage, without which no precautions will avail. It is most important to take care that earth should not lie in contact with the walls of a building, for the damp is quickly communicated, in that case, by their means to the ends of timbers, and rot soon follows. No expedient to guard against this contingency is so good as what are called air or dry drains, which are areas formed by thin walls round the building, with apertures in the paving laid between them and the principal walls, so as to afford a constant current of fresh air.

1751. When the carcass of a building is complete, it should be left as long as possible to dry, and to allow to the timbers what may be called a second seasoning. The modern practice of finishing buildings in the quickest possible period, has contributed more to dry rot than perhaps any other cause; and for this the architect has been blamed instead of his employer, whose object is generally to realize letting or to enjoy occupation of them as early as possible. After, however, the walls and timbers of a building are once thoroughly dry, all means should be employed to exclude a fresh accession of moisture, and delay becomes then prejudicial.

1752. We have before noticed corrosive sublimate in solution as a wash useful in the prevention of decay, and have also ourselves found that a weak solution of vitriolic acid with water will generally stop the rot if it have not gone too far. But it is extremely difficult to prevent the spreading of the fungus of the dry rot after it has once commenced; and the precautions indicated above, although not always successful, are better than the being reduced to after remedies. Certain, however, it is, that the washes we have named will often prevent the infection from spreading. Pyrolichnous acid has recently been recommended, and, we think, very usefully, as a remedy for preventing the spreading of the disease.

CURE OF ROT.

1753. It is no easy matter to cure the rot where it has once taken root. If it be found necessary to substitute new timbers for old ones, every particle of the fungus must be removed from the neighbourhood of such new timbers. After scraping it from the adjoining walls and timbers, perhaps no better application than one of the washes above mentioned can be employed, inasmuch as they can always be with safety applied to the parts. An extraordinary degree of heat would effect the same purpose, but this, especially in the case of floors, is difficult in application. Coal tar has been found useful, but its extremely unpleasant odour is an objection.

Sect. V.

IRON.

1754. Iron is a metal found in almost all parts of the world, and though not mentioned by Homer, and hence, we may suppose, in his time extremely scarce, it is now more abundant than any of the other metals, and is, at the same time, the most useful. Although, with the exception of tin, it is the lightest of all metals; yet it is, when pure, very malleable and extremely hard. Its malleability is increased by heat, whereas most other metals, as they are heated, become more brittle. It is the only known substance whereon the loadstone acts, and its specific gravity to water is as 7632 to 1000.

1755. The iron manufactured in Great Britain is obtained from three species of the ore. The *Lancashire*, which is very heavy, fibrous in texture, and of a dark purple colour inclining to black, and lodged in veins. The *Bog ore*, which has the appearance of a deep yellow clay, and is found in strata of from twelve to twenty inches in thickness. And lastly, *Iron stones*, of an irregular shape, frequently in beds of large extent, similar to other stony masses, and often intersected with seams of pit coal. It is principally from the argillaceous ore or clay iron-stone that iron is extracted in this country.

1756. After raising, the ores are selected and separated as much as possible from heterogeneous substances. They are then roasted in large heaps in the open air, for the purpose as well of freeing them from the arsenic and sulphur they contain as to render them friable or easy of reduction to a powder. The roasting is performed by means of bituminous coal, and the result is a substance full of fissures, friable, and a deprivation of all vitreous lustre. After this it is transferred to the crushing mill for complete pulverization, whence it is carried to the smelting furnace for conversion into iron. Herein it undergoes two separate processes: first, the reduction of the oxide to a metallic state; second, the separation of the earthy particles in the form of scoria. These operations are conducted by submitting the ore, ordinarily mixed with certain fluxes, to the action of carbon at a very high temperature, in what are called blast furnaces, which vary in height from twelve to sixty feet, and are of the form of truncated pyramids, terminating usually in cylindrical chimneys, whose internal diameter is from four to six feet. The interior of these furnaces is usually of a cylindrical form, whose internal diameter is from four to six feet. The cavity of these furnaces is usually of a circular form, except at the *crucible* or *hearth*, where it becomes a right rectangular prism, oblong in a direction perpendicular to the blast orifices or *tuyeres* of the bellows. The sides of the crucible are most commonly formed of gritstone. The *boshes*, which are in the form of an inverted quadrangular pyramid approaching a prismatic shape, are placed above the crucible, and above them rises the conical body of the furnace, which is lined with fire-bricks, and, in ascending, is contracted similarly to the narrow end of an egg, until it terminates in the chimney. The furnace is of course constructed in the most solid manner, and strengthened by iron bands and bars. The bellows employed are mostly of a cylindrical form, and their pistons worked either by water or steam. The blast holes, which are in the upper part of the crucible, and frequently placed on opposite sides, but so that the two opposite currents may not impinge upon one another, are two in number. Openings are provided at the lower part of the crucible for the discharge of the metal and scoria, and are kept stopped by clay and sand upon the exterior when the furnace is in operation. The reduction is commenced by gradually heating up the furnace until capable of being entirely filled with fuel, and then, as its contents begin to sink, alternate changes of ore, mingled with *flux*, and of charcoal and coke, are added. The blast is now let on, and the metal in the ore, parting with its oxygen, flows by degrees, subsiding to the bottom of the crucible, covered with a melted *slag*, which is occasionally let off by removing the clay from one or more, if necessary, apertures in the crucible; and on the bottom of the furnace becoming filled with the metal, which generally occurs after nine to twelve hours, the iron itself is discharged by one of these openings into a fosse of sand mixed with clay. When the iron has flowed out the aperture is again closed, and by this method the furnace is kept in constant action.

1757. Limestone of the best quality is employed as a flux to assist the fusion of the ore, which it accomplishes by vitrefying the earths wherewith it is mixed up with the oxide of iron. The iron when run out from the blast furnace in the state of cast iron is far from being in a pure state, having a coarse grain, and being brittle. In its conversion to bar iron, it undergoes one of the two following processes, as charcoal or coke may be employed. In the former case a furnace much resembling a smith's hearth is used, having a sloping cavity sunk from ten to twelve inches below the blast pipe. After the cavity has been filled with charcoal and scoria, a pig of cast iron, well covered with hot fuel, is placed opposite the blast pipe. The blast being introduced, the pig of iron lying in the very hottest part soon begins to melt, and runs down into the cavity below, where, being out of the influence of the blast, it becomes solid, and is replaced in its former position, and the cavity is again filled with charcoal. It is there again fused, and so on a third time, all these processes being accomplished in three or four hours. The iron, thus again solid, is taken out, and very slightly hammered, to free it from the attached scoria; after this it is returned to the furnace, in a corner whereof it is stacked, out of the action of the blast, and well covered with charcoal, where it remains gradually to cool until sufficiently compact to bear the *tilt*, or *trip hammer*, which is moved by machinery, and whose weight is from 600 to 1200 lbs. Thus it is beaten till the scoriæ are forced out, when it is divided into several portions, which, by repeated heating and hammering, are drawn into bars, in which state it is ready for sale.

1758. There are various methods of procuring the blast, which we think it unnecessary here to detail: the first, and most ancient, are by means of bellows; the latest, which has been found in the mining districts to be a contrivance of great importance, is the placing a series of vanes attached to an axis, which are made to revolve in a box with great rapidity. A pipe passing from the outside of the box to the furnace conveys the air to it as the vanes revolve, a new portion continually entering by a hole at the axis.

1759. The proportion of pig or cast iron from a given quantity of ore varies as the difference in the metallic contents of different parcels of ore and other circumstances, but the quantity of bar obtained from pig iron is not valued at more than 20 per cent.

1760. The other process for manufacturing bar iron, which is that chiefly employed in this country, is conducted in reverberatory furnaces, usually called *puddling furnaces*. The operation begins with the fusion of the cast iron in refinery furnaces, like the one above described. When the iron is fully melted, a tap-hole is opened in the crucible, and the metal and slag flow out together into a fosse covered with clay well mixed with water, by which a coating is formed that prevents the metal from sticking to the ground. The finer metal forms a slab about ten feet long, three feet broad, and from two to two and a half inches in thickness. For the purpose of slightly oxidizing it, and to make it brittle, it is much sprinkled over with cold water. In this part of the process it loses in weight from 12 to 17 per cent. After this, it is broken up into pieces, and placed on the hearth of a reverberatory furnace, in portions heaped up to its sides in piles which rise nearly to the roof, leaving a space open in the middle to give room for puddling the metal as it flows down in streams. When the heat of the furnace has brought it to a pasty state, the temperature is reduced, a little water being sometimes thrown on the melted mass. The semi-liquid metal is stirred up by the workman with his *puddle*, during which it swells, and parts with a large quantity of oxide of iron, which burns with a blue flame, so that the mass appears ignited. As it refines, the metal becomes less fusible, or, as the workmen say, it begins to *dry*. The puddling goes on until the whole charge assumes the form of an incoherent sand, when the temperature is gradually increased to give it a red white heat, at which period the particles begin to agglutinate, and the charge, in technical language, *works heavy*. The refining is now considered finished, and the metal has only to be formed into balls, and condensed under the rolling cylinder. From this state it is brought into *mill bar iron*. After this last operation, several pieces are welded together, from which it acquires ductility, uniformity, and cohesion. A lateral welding of four pieces together now follows, and the mass passes through a series of cylinders as in the first case, and becomes English bar-iron.

1761. The lamination of iron into sheets is by a refinery furnace, with a charcoal instead of a coke fire.

1762. Malleable iron is often obtained from the ores directly, by one fusion, if the metallic oxide be not too much mixed with foreign substances. It is a mode of working much more economical than that above described, and from the circumstance of its having been long known and used in Catalonia, it is known by the name of the *method of the Catalonian forge*. The furnace employed is similar to the refiner's forge already described. The crucible is a kind of semicircular or oblong basin, eighteen inches in diameter, and eight or ten in depth, excavated in an area, or small elevation of masonry, eight or ten feet long, by five or six broad, and covered in with a chimney. The tuyere is placed five or six inches above the basin, inclining a little downwards, and the blast is received from a water blowing machine. The first step consists in expelling the water combined with the oxide, as well as the sulphur and arsenic when these are present. This, as usual, is done by roasting in the open air, after which it is reduced to a tolerably fine powder, and thrown at intervals by shovels-full upon the charcoal fire of the forge hearth, the sides and bottom of the basin being previously lined with *brasques* (coats of pounded charcoal). It gradually softens and unites into lumps more or less coherent, which finally melt and accumulate in the bottom of the crucible or basin. A thin slag is occasionally let off from the upper surface of the melted metal in the basin through holes which can be closed and opened at the discretion of the workman. The melted iron preserves a pasty condition owing to the heat communicated from above. When a mass sufficiently great has accumulated, it is removed, put under the hammer, and forged at once. A lump, or bloom, of malleable iron is thus produced in the space of three or four hours. Four workmen are employed at one forge, and by being relieved every six hours, they are enabled to make 86 cwt. of iron per week. In the Catalonian forge, 100 lbs. of iron are obtained from 300 lbs. of ore (a mixture of sparry iron, or carbonate and hemalite), and 310 lbs. of charcoal, being a produce of 33 per cent.

1763. A visit to some of the iron districts is necessary fully to understand the processes we have above shortly described; but the founding of iron may be well enough observed in the metropolis, though not on so large a scale as in some of the provinces.

1764. The sand employed in casting is of a soft yellow and clammy nature, over which, in the mould, charcoal is strewed. Upon the sand properly prepared, the wood or metal models of what is intended to be cast are applied to the mould, and pressed so as to leave their impression upon the sand. Canals are provided for the metal, when melted, to run through. After the frame is finished, the patterns are taken out by loosening them all round, that the sand may not give way. The other half of the mould is then worked with the same patterns, in a similar frame, but having pins which, entering into holes that correspond to it in the other, cause the two cavities of the pattern exactly to fall on each other. The frame thus moulded comes now under the care of the melter, who prepares it for the reception of the metal.

1765. All castings should be kept as nearly as possible of the same bulk, in order that the cooling may take place equably. It is of importance to prevent air bubbles in castings, and the more time there is allowed for cooling the better, because when rapidly cooled, the iron does not become so tough as when gradually cooled.

1766. In making patterns for cast iron, an allowance should be made of about one eighth of an inch per foot for the contraction of the metal in cooling. And it may be also requisite that the patterns should be slightly bevelled, that they may be drawn out of the sand without injuring the impression; for this purpose a sixteenth of an inch in six inches is sufficient.

1767. The security afforded, not only for supporting weight, but against fire, has, of late years, very much increased the use of it, and may in many cases entirely supersede the use of timber. Again, it is valuable from its being not liable to sudden decay, nor soon destroyed by wear and tear, and, above all, from its plasticity.

1768. Soft grey cast iron is the best sort; it yields easily to the file when the external crust is removed, and is slightly malleable in a cold state. It is, however, more subject to rust than the white cast iron, which sort is also less soluble in acids. Hence the white sort may be employed where hardness is necessary and brittleness not a defect. Grey cast iron has a granulated fracture with some metallic lustre, and is much softer and tougher than the white cast iron. The white cast iron in a recent fracture has a white and radiated appearance, indicating a crystalline structure.

1769. The most certain test of the goodness of a piece of cast iron is by striking the edge with a hammer, which if it make a slight impression, denoting some degree of malleability, the iron is of a good quality. It is important in any casting to have the metal as uniform as possible, and not of different sorts, for different sorts will shrink differently, and thus will be caused an unequal tension among the parts of the metal, which will impair its strength: and, beyond this, an unevenness is produced by such mixture in the casting, for different sorts can never be perfectly blended together.

1770. It is well known, also, that iron varies in strength, not only in samples from different furnaces, but even from the same furnace and the same melting. This, however, seems owing to some imperfection in the casting, notwithstanding which, it is, when well mixed, capable of resisting the greatest stresses in mill and engine work.

1771. The transverse strength of cast iron, as of any other body, is that power which it exerts in opposing a force acting in a direction perpendicular to its length, as in the case of beams, levers, and the like It is well known that the transverse strengths of beams, &c. are inversely as their lengths, and directly as their breadths and the squares of their depths. If cylinders, that they are as the cubes of their diameters. Thus, if a beam 6 feet long, 2 inches broad, and 4 inches deep, will bear 5000 lbs., another of the same scantling, and double the length, will only bear 2500 lbs., being inversely as the lengths. So, if a beam 6 feet long, 2 inches broad, and 4 inches deep will support a weight of 5000 lbs., another beam of the same material, twice the breadth, that is, 4 inches, will support 10,000 lbs., that is, double, being directly as the breadths; but a beam of the same material 6 feet long, 2 inches broad, and 8 inches deep, will sustain 20,000 lbs., being as the squares of their depths. From a mean of several experiments on cast iron, it may be assumed that the ultimate or breaking strength of a bar of cast iron 1 inch square and 1 foot long, loaded in the middle, was 2580 lbs.; and taking one third, or 860 lbs., as the weight which will not destroy its elasticity, we thus obtain constants for guiding us in the ordinary computations for the sizes of girders, beams, bressummers, &c. The strongest form of the section of a beam to resist a cross strain is this . We do not however think it here necessary to give much more than the rules for finding their breadths and depths, considered as simple figures. The principles on which the rules subjoined are founded may be seen in Gregory's *Me-*

chanics, and Barlow *On the Strength of Materials*, but divested, certainly, of the refinement of Dr. T. Young's *Modulus of Elasticity*, and some other matters, which we cannot help thinking unnecessary in a subject where, after exhausting all the niceties of the question, a very large proportion of weight is still considered too much for the constant load to be imposed on the examples.

1772. PROBLEM I. To find the ultimate strength of a rectangular beam of cast iron supported at both ends, and loaded in the middle, we have only to multiply the breadth into the square of the depth, and that again by the constant 2580, and the last product divided by the length in feet will be a quotient expressing the weight in pounds averdupois, nearly.

Example. What weight will break a cast iron beam 2 inches broad, 6 inches deep, and 15 feet between the supports?

$$\text{Here } \frac{2580\times 2\times 6^2}{15}=12384 \text{ lbs.}$$

If a beam be supported at the middle and loaded at each end, it will bear the same weight as when supported at both ends and loaded in the middle. It may be here observed, that the following rules hold good for inclined as well as horizontal beams, if the horizontal distance between the supports be taken for the bearing.

1773. PROBLEM 2. To find the ultimate strength of a cast iron beam when the weight is placed somewhere between the middle and the end. Multiply twice the length of the longer end by twice the length of the shorter end, which divided by the product will give the effectual length. Using the effectual length thus found as the length in Problem 1., the question may be answered.

Example. What is the ultimate strength of a cast iron beam 15 feet between the supports, 2 inches wide, and 6 inches deep, the weight being placed at 5 feet from one end?

$$\text{Here } \frac{(2\times 10)\times(2\times 5)}{15}=13\cdot 33 \text{ effective length, and } \frac{2580\times 2\times 6^2}{13\cdot 33}=13934 \text{ lbs.}$$

In the case of any beam fixed at one end and loaded at the other, it is known that it will bear only one fourth of the weight it will bear in the middle when supported at both ends. Thus for

Example. What weight will break a cast iron beam 2 inches wide and 6 inches deep, projecting 15 feet from the point of support?

$$\text{Here } \frac{2580\times 2\times 6^2}{15}=\frac{12384}{4}=3096 \text{ lbs. (See Prob. 1.)}$$

1774. The above rules are equally applicable to beams whose forms are cylindrical, except that in such case the absolute strength of a round bar (for which in that of cast iron the constant is for the breaking weight 2026, one third whereof is 675 for cast iron) is found by multiplying by the cube of the diameter instead of by the breadth and square of the depth.

Example. What is the ultimate transverse strength of a cast iron cylinder 15 feet long and 6 inches diameter?

$$\text{Here } \frac{2580\times 6^3}{15}=37152 \text{ lbs.}$$

In the case of a hollow shaft of cast iron of the same length as in the last example, whose diameter is 9 inches, but whose cross sectional area is the same as a solid cylinder 6 inches diameter,

$$\text{We have } \sqrt{9^2-6^2}=6\cdot 708, \text{ and } 9^3-6\cdot 708^3=426\cdot 9.$$

$$\text{Then } \frac{2580\times 426\cdot 9}{15}=73{,}427 \text{ lbs.}$$

1775. The following points relative to loads on beams are to be here noted. I. If any beam be fixed at both ends, when loaded in the middle, it is capable of bearing one half more than it will if both ends are loose. II. If loose at both ends, and the weight be applied uniformly along its length, it will support double. III. If it be fixed at both ends, and the weight be applied uniformly along its length, it is capable of bearing triple the weight.

1776. In cases where beams of cast iron are intended to support a permanent weight, the application of the following problem is necessary, in which 860, or one third of the breaking weight, is used.

1777. PROBLEM III. To find the breadth or depth of beams which shall support a given permanent weight. The length between the supports must be multiplied by the weight to be supported in pounds, and the product divided by one third (860) of the ultimate strength of an inch bar multiplied by the square of the depth, and the quotient will be the breadth. If multiplied by the breadth, the quotient will be the square of the depth, both in inches.

Example. What should be the breadth of a cast iron beam 15 feet long and 6 inches deep, to support 3 tons in the middle? (3 tons = 6720 lbs.)

$$\text{Here } \frac{6720 \times 15}{860 \times 6^2} = 3{\cdot}25 \text{ inches, full.}$$

Example. What depth should be given to a cast iron beam 3·25 inches broad and 15 feet long, to bear a permanent weight of 3 tons in the middle?

$$\text{Here } \frac{6720 \times 15}{860 \times 3{\cdot}25} = 36{\cdot}06, \text{ whose square root is 6 inches.}$$

Example. Suppose a cast iron beam 15 feet long and 6 inches deep, made fast at both ends, to be loaded with a permanent weight of 3 tons in the middle, what should be its breadth?

$$\text{Here, from the last problem, } \frac{6720 \times 15}{860 \times 6^2 \times 1{\cdot}5} = 2{\cdot}17 \text{ inches.}$$

A beam when fixed at one end and loaded at the other is known to bear only one fourth of the weight; one quarter of the divisor must therefore be taken, or, which is the same, it may be multiplied by ·25.

Example. What should be the depth of a beam 3 inches broad, to project 10 feet from a wall, and to be loaded with a weight of 3 tons = 6720 lbs.?

$$\text{Here } \frac{6720 \times 10}{860 \times 3 \times {\cdot}25} = 104, \text{ whose square root } = 10{\cdot}19 \text{ inches.}$$

When the weight is not placed in the middle of the beam, the effective length must be obtained as in Problem 1.

Example. What depth should be assigned to a cast iron beam 15 feet long and 3 inches broad, to support a weight of 3 tons = 6720 lbs., 5 feet from one end?

$$\text{Here } \frac{(2 \times 10) \times (2 \times 5)}{15} = 13{\cdot}33, \text{ effective length of the beam.}$$

$$\text{And } \frac{6720 \times 13{\cdot}33}{860 \times 3} = 34{\cdot}7, \text{ whose square root } 5{\cdot}9 \text{ inches, nearly.}$$

The strength of cast iron to wrought iron is as 9 to 14, nearly.

N.B. All the above rules may be applied in common practice to find the scantlings of beams by using the following factors instead of that of cast iron, such factors being the ultimate transverse strengths of a bar 1 inch square and 1 foot long of the different sorts of timber to which they are attached.

Ash - -	- 1137,	one third whereof is	379
Pitch pine -	- 916	—	305
Oak - -	- 800	—	209
Elm - -	- 569	—	149
Fir - -	- 566	—	148

1778. The greatest variable load on a floor, except in public rooms, seldom exceeds 120 lbs. to the square foot, whence the reader may form a pretty accurate notion of the quantity of strain against which he has to provide.

1779. The cohesive strength of cast iron, from some of the latest experiments, was found in horizontal casting to be equal to 18,656 lbs. per square inch, and in vertical casting 19,488 lbs. to the square inch. One third, therefore, of 18,656 = 6219 may be used as the factor in computations of the permanent cohesive strength of cast iron. In English wrought iron the experiment gives 55,872 lbs. for the cohesive strength per square inch of English wrought iron, and for Swedish, 72,064 lbs. per square inch. If, therefore, it be required to find the ultimate cohesive strength of bars of cast or wrought iron, the area of their section being found, and multiplied by the relative cohesive strengths above mentioned, the product will be the ultimate cohesive strength, nearly. Thus for

Example. What is the cohesive power of a bar of cast iron 1½ inch square?

$$\text{Here } 1{\cdot}5 \times 1{\cdot}5 \times 18656 = 41976 \text{ lbs., nearly.}$$

If the weight to be sustained be given, and the sectional dimensions of the bar be required, we must divide the weight given by one third of the cohesive strength of an inch bar, and the square root of the quotient will be the side of the square.

Example. What dimension must be given to the side of a square bar of Swedish iron to sustain a permanent weight of 18,000 lbs., $\frac{72064}{3} = 24{,}021$ lbs. being, as above mentioned, the permanent load a square inch will sustain.

$$\text{Here } \sqrt{\frac{18000}{4021}} = {\cdot}86, \text{ or } \tfrac{7}{8} \text{ of an inch square.}$$

If the section be rectangular, the quotient must be divided by the breadth.

Example. If the breadth of an English wrought iron bar which is required to carry 3000 lbs. be 2½ inches, required its thickness. The permanent cohesive strength $= \frac{55872}{3} = 18624$.

$$\text{Here } \frac{3000}{18624} = {\cdot}161, \text{ and } {\cdot}161 + 2{\cdot}5 = {\cdot}064 \text{ of an inch in thickness.}$$

1780. The power of the resistance to compression was heretofore very much overrated. It has been well ascertained by experiment, that a force of 93,000 lbs. upon a square inch will crush it; and that it will bear 15,300 upon a square inch without permanent alteration. The weight of cast and bar iron is as follows: —

	Weight of a cubic foot in ounces.	Weight of a cubic foot in pounds.	Weight of a cubic inch in pounds.
Cast	7207	450·5	0·260
Bar	7788	486·8	0·281

Sect. VI.

LEAD.

1781. Lead, the heaviest of the metals except gold and quicksilver, is found in most parts of the world. It is of a bluish white when first broken, is less ductile, elastic, and sonorous than any of the other metals, its specific gravity being from 11300 to 11479, and a cubic foot, therefore, weighing about 710 lbs. It is soluble in all acids and alkaline solutions, fusible before ignition, and easily calcined. The ore, which is easily reduced to the metallic state by fusion with charcoal, is found mineralised with sulphur, with a slight mixture of silver and antimony, in diaphanous prismatical crystals, generally hexagonal, white, yellowish, or greenish, in Somersetshire, about the Mendip Hills. About Bristol, and in Cumberland, it takes the form of a white, grey, or yellowish spar, without the least metallic appearance; in some places it is in a state of white powder or native ceruse; and in Monmouthshire it has been found native, or in a metallic state.

1782. Exposure to air and water does not produce much alteration in lead, though it quickly tarnishes and acquires a white rust, by which the internal parts are defended from corrosion. Pure water, however, does not alter it; hence the white crust on the inside of lead pipes through which water flows must probably be owing to some saline particles in the water. Lead will form an union with most other metals: one exception, however, is iron. Next to tin, it is the most fusible of metals. It is run from the furnace into moulds which form what are called *pigs*, from which it is run into sheets, pipes, &c.

1783. Sheet lead is of two sorts, *cast* and *milled*. The thicker sort of the former, or the common cast sheet lead, is manufactured by casting it on a long table (with a rising edge all round it) from 18 to 20 feet in length, which is covered with fine pressed sand beaten and smoothed down with a strike and smoother's plane. The pig lead is melted in a large vessel, near this table, and is ladled into a pan of the shape of a common triangular prism, whose length is equal to the width of a sheet, from which pan it is poured on to the table or mould. Between the surface of the sand and the *strike*, which rides upon the edges of the table, a space is left which determines the thickness of the sheet. The strike bears away the superfluous liquid lead before it has time to cool, as it moves by hand along the edges of the table before mentioned. When lead is required to be cast thin, a linen cloth is stretched on an appropriate table over a woollen one; in which case the heat of the lead, before spreading it on the cloth, must be less than will fire paper, or the cloth would be burnt. The strike must for the purpose be passed over it with considerable rapidity.

1784. In manufacturing milled lead, it is usual first to cast it into sheets from 8 to 10 feet long according to circumstances, but the width is regulated by the length of the rollers through which it is to be passed in milling; the thickness varies from 2 to 5 inches. By a mechanical action it is made to pass through rollers whose distance from each other is gradually lessened until the sheet is reduced to the required thickness. For a long time a great prejudice prevailed against milled sheet lead; but it is now generally considered that, for the prevention of leakage, milled is far superior to cast lead, wherein *pin holes*, which have naturally formed themselves in the casting, often induce the most serious consequences.

1785. The thickness of sheet lead varies from 5 to 12 pounds in weight to the superficial foot, and is used in covering large buildings, in flats or slopes, for gutters, the hips, ridges, and valleys of roofs, the lining of cisterns, &c. The subjoined table shows the weight of lead per superficial foot from one sixteenth of an inch to one inch and a half thick: —

Thickness.	Weight.	Thickness.	Weight.
One sixteenth of an inch	3¾ lbs.	One fourth of an inch	14¾ lbs.
One twelfth	5	One third	19¾
One tenth	6	One half	29½
One eighth	7½	Three quarters	44¼
One sixth	10	One inch	59
One fifth	12	One inch and a half	88½

Leaden pipes are either cast bent, or soldered. To cast them, a mould is made of brass, wherein down the middle a core of iron is loosely supported at such a distance from the mould all round, as is equal to the contemplated thickness of the pipe. When pipes are made by soldering, a core of wood is provided round which the sheet lead is rolled, and the edges are brought together and joined with *solder*, which is a mixture of two parts lead and one part tin.

1786. In cottages and inferior buildings the glazing is executed in lead prepared in the glazier's mill from what are called *cames*. These are slender rods 12 or 14 inches long, and in passing through the mill receive grooves on their upper and under edges. Into the grooves the panes or quarries of glass are inserted in common lead lights.

Sect. VII.

COPPER.

1787. Copper, among the first of the metals employed by the early nations of the world, is neither scarce nor difficult to work and extract from its ore. When pure it is of a pale red colour, its specific gravity 8600, and a cubic foot will weigh 537½ lbs.; the weight of a bar 1 foot long and 1 inch square is 3·81 lbs. These, however, vary as it is more or less hammered. Its elasticity and hardness are very considerable, and it is so malleable that it may be hammered into fine leaves. It is also very tenacious, a wire of a tenth of an inch in diameter being capable of sustaining 360 lbs.

1788. Though the ore is found in Cornwall and other parts of England, the finest in this country is the Parys mine in Anglesea, which yields principally the yellow sulphuretted ore of copper, to an annual amount of from 40,000 to 80,000 tons. This ore usually contains from one and a half to twenty-five per cent. of copper, and is partly dug in what are called *packages*, and partly blasted by gunpowder, and then broken into small pieces previous to its being roasted. This operation is performed in kilns, whose shape has a resemblance to lime-kilns, in which expedients are used for removing the ore as it is roasted, and adding fresh ore. The kilns are arched level with the upper surface of the ore, and adjoining and communicating with the kiln is the floor of a condensing chamber to receive the sulphureous vapours generated in the kiln, which fall down in the form of the finest flowers of sulphur. Several hundred tons at one time are put into the kiln, and for completing the operation six months are required. The ore is reduced to one fourth of its previous quantity by roasting, and is then washed and pressed to remove the impurities. The richer ores are then dried, and removed for smelting and refining in reverberatory furnaces, from which it is at length produced in short bars or pigs. The water which filters through the fissures is often highly impregnated with sulphate of copper, and this water is pumped up into rectangular pits about thirty feet long, twelve broad, and two deep, to mix with that in which the roasted ore has been washed; and in it are immersed pieces of iron, which, combining with the sulphuric acid, precipitate the copper in the form of a red-coloured powder slightly oxidated. The precipitate thus obtained very frequently gives above 50 per cent. of pure copper, and is even more profitable to the worker than the metal produced from the crude ore.

1789. Sheet copper was formerly much used for its lightness to cover roofs and flats; but it is almost superseded now by the use of zinc, which is much cheaper, and nearly if not quite as durable; and which, moreover, is not so liable to be corrugated by the action of the sun. Copper is reduced to sheet by being passed through large rollers, by which it can be rendered very thin. The thickness generally used is from 12 to 18 ounces to the foot superficial. Exposed to the air its lustre is soon gone; it assumes a tarnish of a dull brown colour, gradually deepening by time into one of bronze; and, lastly, it takes a green rust or calx, called *patina* by the antiquaries, which, unlike the rust of iron, does not injure and corrode the internal parts, confining itself to the surface, and rather preserving than destroying the metal. Hence, one of the most important applications of copper is in cramps for stone work, especially when they are exposed to the air. It may be here well to observe, that if water is collected from roofs for culinary purposes, copper must not be used about them, neither should any reservoirs for collecting and holding it be made of that metal.

1790. Alloyed with zinc, it forms brass for the handles of doors, shutters, locks, drawers, and the furniture generally of joinery. The usual proportion is one part of zinc to three of copper; than which it is more fusible, and is of a fine yellow colour, less liable to tarnish from the action of the air, and so malleable and ductile that it can be beat into thin leaves and drawn into very fine wire. Its specific gravity is 8370, and the weight of a cubic foot is 523 lbs. The weight of a bar 1 foot long and 1 inch square is 3·63 lbs. The extremes of the highest and lowest proportions of zinc used in it are from 12 to 25 per cent. of the brass. Even with the last, if well manufactured, it is quite malleable, although zinc by itself scarcely yields to the hammer. The appearance of brass is frequently given to other metals by washing them over with a yellow lacquer or varnish.

1791. Copper with zinc in the proportion of one tenth to one fifth of the whole forms a composition called bronze or bell-metal, used in the foundery of statues, bells, cannons, &c. When tin forms nearly one third of the alloy, a beautiful white close-grained brittle metal is formed, susceptible of a very high polish, which is used for the specula of reflecting telescopes.

Sect. VIII.

ZINC.

1792. Zinc is found in all quarters of the globe. In Great Britain it is abundant, though therein never found in a native state. It usually contains an admixture of lead and sulphur. When purified from these, it is of a blue light colour, between lead and tin, inclining to blue. The ore, after being hand-dressed to free it from foreign matter, is roasted, by which the sulphur of the calamine and the acid of the blende are expelled. The product is then washed to separate the lighter matter, and the heavy part which remains is mixed with one eighth of its weight of charcoal. The mixture, being reduced in a mill to a powder, is placed in the pots, resembling oil jars, to be smelted. A tube passes through the bottom of each, the upper end being terminated by an open mouth near the top of the pot, and the lower end going through the floor of the furnace into water. The pots being filled with the mixture of ore and charcoal, an intense heat is applied to them by means of a furnace, by which, as the ore is reduced, the zinc is volatilized, and escapes through the tube into the water, wherein it falls in globules, which are afterwards melted and cast into moulds. Thus procured, however, it is not pure, as it almost invariably contains iron, manganese, arsenic, and copper. In order to free it from these, it is again melted and stirred up with sulphur and fat, the former whereof combines with the heterogeneous metals, leaving the zinc nearly pure, and the latter preventing the metal from being oxidated.

1793. Under rollers at a high temperature, zinc may be extended into plates of great tenuity and elasticity, or drawn into wire. These rollers are from 2 feet 8 inches to 6 feet in length, and the original thickness of the plate subjected to them is about 1 inch. A wire, one tenth of an inch diameter, will support 26 pounds. If zinc be hammered at a temperature of 300°, its malleability is much increased, and it becomes capable of much bending. Its fracture is thin, fibrous, and of a grain similar to steel. It can be drawn into wire $\frac{1}{200}$th of an inch in diameter, which is nearly as tenacious as that of silver. The specific gravity is somewhat below 7·0, but hammering increases it to 7·2. When heated, it enters into fusion at a heat of about 680° or 700°: at a higher temperature it evaporates; and if access of air be not permitted, it may be distilled over, by which process it is rendered purer than before, although not then perfectly pure. When heated red hot, with access of air, it takes fire, burns with an exceedingly beautiful greenish or bluish flame, and is at the same time converted into the only oxide of zinc with which we are acquainted, consisting of 23·53 parts of oxygen combined with 100 of metal.

1794. On the first introduction of zinc into this country as a material, the trades with which it was likely to interfere used every exertion to prevent its employment; and, indeed, the workmen who were engaged in laying it, being chiefly tinmen, were incompetent to the task of so covering roofs as to secure them from the effects of the weather. Hence, for a considerable period after its first employment, great reluctance was manifested by architects in its introduction. A demand for it has, however, gradually increased of late, and the comparatively high prices of lead and copper will not entirely account for the disparity of consumption. In France, in the year 1836, the quantity consumed exceeded 12,000 tons, whilst, in the same year, in England the consumption amounted only to between 2000 and 3000 tons.

1795. Zinc, though subject to oxidize, has this peculiarity, that the oxide does not scale off as that of iron, but forms a permanent coating on the metal, impervious to the action of the atmosphere, and rendering the use of paint wholly unnecessary. Its expansion and contraction is greater than those of any other metal: thus, supposing 1·0030 to represent the expansion of it, 1·0019 is that of copper, and 1·0028 that of lead; hence, in use, proper attention must be paid to the circumstance, or a substantial and durable covering of zinc will not be obtained. The method of accomplishing this is, of course, by always allowing plenty of *play* in the *laps*.

1796. The tenacity of zinc to lead is as 16·616 to 3·328, and to copper as 16·616 to 22·570; hence a given substance of zinc is equal to five times the same substance in lead, and about three fourths of copper. The sheets in general use are 12, 14, 16, 18, and 20 ounces to the foot superficial; and as 18 thicknesses of 16 ounces to the foot are half an inch thick, the following show the thicknesses of the different weights: —

Plates or sheets of 10 ounces to the foot are		0·0611 inch thick.	
12	—	0·0457	
14	—	0·0534	
16	—	0·0611	- - = $\frac{1}{36}$ of an inch.
18	—	0·0686	
20	—	0·0761	

The comparative weights of the different materials used in covering buildings may be roughly stated as follows: —

A square of pantiling will weigh about		7½ cwt.
plain tiling	—	14½ cwt.
slating (a mean)	—	6½ cwt.
lead	—	5 cwt.
zinc (15 oz.)	—	1 cwt.

And as the timbers employed, of course, are less in dimension as the weight diminishes, it follows that a less quantity of timber is requisite when zinc can be employed.

1797. It is a good material for water-cisterns and baths, rain-water pipes, — in short, for almost all purposes where lead has been hitherto employed; and latterly a method has been invented, by which it is formed into sash-bar for skylights and ornamental sashes; for which purposes, strength excepted, it is superior to iron, as not being liable to rust, and loosen the putty and glass. It is, in every respect, equal to copper, and not more than one third the cost of it.

Sect. IX.

SLATES.

1798. Slate is a species of argillaceous stone, and is an abundant and most useful mineral. The slate district in England is of considerable extent. This material is so soft, that the human nail will slightly scratch it, and is of a bright lamellated texture. Its constituent parts are argyll, earth, silex, magnesia, lime, and iron; of the two first and the last in considerable proportion. The building slate is the *schistus tegularis*.

1799. The slates used about London are brought chiefly from Bangor, in Caernarvonshire; but the most esteemed is a pale blue-green slate, brought from Kendal, in Westmorland, and called Westmorland slates. Those from Scotland are not in much repute. Slate quarries usually lie near the surface; and, independent of the splitting grain, along which they can be cleft exceedingly thin, they are mostly divided into *stacks*, by breakings, cracks, and fissures. Slate is separated from its bed, like other stones, by means of gunpowder, and the mass is then divided into scantlings by wedges, and, if necessary, sawn to its respective sizes by machinery. The blue, green, purple, and darker kinds are most susceptible of thin cleavage, the lighter-coloured slates being coarser. The instruments used in quarrying and splitting slates are slate-knives, axes, bars, and wedges. In fixing them on roofs the *zax* is used. This is an instrument made of tempered iron, about 16 in. long and 2 in. wide, like a large knife bent a little at one end, with a wooden handle at the other, and having a projecting piece of iron on its back, drawn to a sharp point, to make holes in the slates for the nails, the other side being used to chip and cut the slates to their required size, as when brought from the quarry they are not sufficiently square and cleaned for the slater's use.

1800. A fine sound texture is the most desirable among the properties of a slate; for the expense of slating being greatly increased by the boarding whereon it is placed, if the slate absorbs and retains much moisture, the boarding will soon become rotten. But a good slate is very durable. Its goodness may be judged of by striking it as you would a piece of pottery, wherefrom a sonorous, clear, bell-like sound is a sign of excellence; but many pieces of the slate should be tried before a conclusion can be arrived at. It is thought to be a good sign, if, in hewing, it shatters before the edge of the zax. The colour, also, is some guide, the light blue sort imbibing and retaining moisture in a far less degree than the deep black-blue sort. The feel of a slate is some indication of its goodness: a good one has a hard and rough feel, whilst an open absorbent slate feels smooth and greasy. The best method, however, of testing the quality of slates is by the use of water, in two ways. The first is, to set the pieces to be judged of edgewise in a tub of water, the water reaching above half way up the height of the pieces: if they draw water, and become wet to the top in six or eight hours' time, they are spongy and bad; and as the water reaches less up them, so are the pieces better. The other method is, to weigh the pieces of slate, and note their weights. Let them then remain for twelve hours in water, and take them out, wiping them dry. Those that on re-weighing are much heavier then they were previous to their immersion should be rejected. Where the character of a slate quarry is not previously known, experiments of these sorts should never be omitted.

1801. The following comparison of the advantages of slates over tiles is given by the late Bishop of Llandaff. That sort of slate, other circumstances being the same, is esteemed the best which imbibes the least water; for the water imbibed not only increases the weight of the covering, but in frosty weather, being converted into ice, swells and shivers the slate. This effect of frost is very sensible in tiled houses, but is scarcely felt in those which are slated, for good slates imbibe but little water; though tiles, when well glazed, are rendered in some measure similar to slate in this respect. The bishop took a piece of Westmorland slate and a piece of common tile, and weighed each of them carefully. The surface of each was about thirty square inches. Both the pieces were immersed in water about ten minutes, then taken out, and weighed as soon as they had ceased to drip. The tile had imbibed about a seventh part of its weight of water, and the slate had not imbibed a two-hundredth part of its weight; indeed, the wetting of the slate was merely superficial. He placed both the wet pieces before the fire; in a quarter of an hour the slate was perfectly dry, and of the same weight as before it was put in the water; but the tile had lost only about twelve grains it had imbibed, which was, as near as could be expected, the very same quantity that had been spread over its surface; for it was the quantity which had been imbibed by the slate, the surface of which was equal to that of the tile. The tile was left to dry in a room heated to sixty degrees, and it did not lose all the water it had imbibed in less than six days. We here subjoin a succinct account of the different sorts of slates brought to the London market, and enumerate them in the order of their goodness and value.

1802. *Westmorland slates.* These are from 3 ft. 6 in. to 1 ft. in length, and from 2 ft. 6 in. to 1 ft. in breadth. They should be nailed with not less than sixpenny and eightpenny copper or zinc nails (iron nails should never be used); and a ton in weight of them will cover about two squares and a quarter. We may here observe, that the weight of the coarsest Westmorland slates is to that of common tiling as 36 to 54.

1803. *Welsh rags* are next in goodness, and are nearly of the same sizes as those last mentioned; but a ton of these will cover only one square and three quarters.

1804. *Imperials* are from 2 ft. 6 in. to 1 ft. in length, and about 2 ft. wide.

1805. *Duchesses* run about 2 ft. long and 1 ft. wide, and are nailed usually so as to show a ten and a half inch gauge.

1806. *Countesses*, of which a ton will cover about three squares, run about 1 ft. 8 in. in length by about 10 in. in width.

1807. *Ladies* are generally about 15 in. long, and about 8 in. wide. These are sold by the thousand of twelve hundred, which quantity will cover about four squares.

1808. There are still other sorts of slates which have been used in and about London, as the *Dennybole*, &c. The *Tavistock slates* were at one period in considerable demand. They are sold by the thousand of ten hundred, which quantity covers about three squares and forty feet. The smallest slates in use are called *Doubles:* they run about 13 in. in length by 6 in. in width. The bond or lap of a slate is the distance between the nail of the under slate and the lower end of the upper slate, and, as in tiling, the gauge in slating is the visible depth of the slate.

1809. Several years ago, a patent was obtained for slating roofs without boarding or battens. In this the slates were all reduced to widths equal to the distance between centre and centre of the rafters. On the backs of these last they are screwed by two or three strong inch and half screws at each of their ends. Over the junctions of the slates, on the backs of the rafters, fillets of slates about two and a half or three inches wide, bedded in putty, are screwed down, to prevent the entrance of rain. The handsome regular appearance of this sort of slating gained it at first much celebrity; but it was soon abandoned, on account of the disorder it is liable to sustain from the slightest partial settlement of the building, not less than from the constant dislodgement of the putty, upon which greatly depended its being impervious to rain.

1810. Slating is sometimes laid lozengewise; but it is much less durable than when laid in the common method.

SECT. X.

BRICKS AND TILES.

1811. A brick is a factitious sort of stone, manufactured from argillaceous or clayey earth, well tempered and squeezed into a mould. When so formed, bricks are stacked to dry in the sun, and finally burnt to a proper degree of hardness in a clamp or kiln. The use of bricks is of the highest antiquity. They are frequently mentioned in the historical books of the Old Testament; but whether they were merely sun-dried or burnt in a kiln seems uncertain. We are inclined to doubt the burning of them at a very remote period. It will immediately occur to the reader that the making of bricks was one of the tasks imposed upon the Israelites during their servitude in Egypt. Though the oldest remains in Egypt are of stone, Pococke describes a pyramid of unburnt bricks, which are composed of a black sandy earth, intermixed with pebbles and shells, the sediment deposited by the overflowing of the Nile. This species of bricks is still common in Egypt and many other parts of the East. By the ancient Greeks and Romans, both burnt and unburnt bricks were used; the method of making the latter whereof is thus described by Vitruvius, in the third chapter of his second book: "I shall first," says that author, "treat of bricks, and the earth of which they ought to be made. Gravelly, pebbly, and sandy clay are unfit for that purpose; for if made of either of these sorts of earth, they are not only too ponderous, but walls built of them, when exposed to the rain, moulder away, and are soon decomposed; and the straw, also, with which they are mixed, will not sufficiently bind the earth together, because of its rough quality. They should be made of earth, of a red or white chalky, or a strong sandy nature. These sorts of earth are ductile and cohesive, and not being heavy, bricks made of them are more easily handled in carrying up the work. The proper seasons for brick-making are the spring and autumn, because they then dry more equably. Those made in the summer solstice are defective, because the heat of the sun soon imparts to their external surfaces an appearance of sufficient dryness, whilst the internal parts of them are in a very different state; hence, when thoroughly dry, they shrink and break those parts which first dried; and thus broken, their strength is gone. Those are best which have been made at least two years; for in a period less than that, they will not dry thoroughly. When plastering is laid and set hard on bricks which are not perfectly dry, the bricks, which will naturally shrink, and consequently occupy a less space than the plastering, will thus leave the latter to stand of itself. From its being extremely thin, and not capable of supporting itself, it soon breaks to pieces; and in its failure, involves sometimes even that of the wall. It is not, therefore, without reason that the inhabitants of Utica allow no bricks to be used in their buildings which are not at least five years old, and also approved by a magistrate.

1812. "There are three sorts of bricks: the first is that which the Greeks call *Didoron* (*διδῶρον*), being the sort we use; that is one foot long and half a foot wide. The other two sorts are used in Grecian buildings; one is called *Pentadoron*, the other *Tetradoron*. By the word *doron*, the Greeks mean a palm, because the word *δῶρον* signifies a gift which can be borne in the palm of the hand. That sort, therefore, which is five palms each way, is called Pentadoron; that of four palms, Tetradoron. The former of these two sorts is used in public buildings, the latter in private ones. Each sort has half bricks made to suit it, so that when a wall is executed, the course on one of the faces of the wall shows sides of whole bricks, the other face of half bricks; and being worked to the line on each face, the bricks on each bed bond alternately over the course below." Vitruvius concludes the chapter with the mention of the bricks made at Calentum in Spain, at Marseilles in France, and Pitane in Asia, which are specifically lighter than water.

1813. It is to be regretted that plastering with cement, a practice which is more to the interest of the brickmaker and bricklayer than to the consumer, has become so prevalent in this country. These tradesmen thus get rid of their worst bricks, which are hidden by a coat of plaster; the building soon decaying when the heart of the wall is bad. Colour seems to be the objectionable quality about this material, the commonplace architect forgetting that form is much more essential to beauty than colour. In the times of Jones and Wren, red brick was beautifully wrought into architectural forms, of which a few examples still remain in the metropolis; and by Palladio, bricks were used for columns without smearing them over with plaster.

1814. In England, the best earth for making bricks is a clayey loam, neither abounding with too much sand, which renders them brittle, nor with too large a portion of argillaceous matter, which causes them to shrink and crack in drying. It should be dug at the least a year before it is wrought, that by exposure to the atmosphere it may part with all extraneous matter which it possessed when first dug. The general practice is, however, to dig it in the autumn, and allow it to remain through the winter to mellow and pulverize, by which the operation of tempering is greatly facilitated. Upon this operation the quality of the brick mainly depends, and great attention should be bestowed upon performing this part of the process in a proper manner. This branch of the manufacture was formerly executed by throwing the clay into shallow pits, and subjecting it to be trodden by men and oxen; a method which has been advantageously superseded by a clay or pug-mill, with a horse track.

1815. As soon as the clay has been thoroughly tempered by one of the methods above named, it is taken to the moulder's bench, where it is cut by the moulder's assistant, generally a woman or a lad, into pieces rather larger than the mould, which are passed on to the moulder, who throws it with some force into the mould, which has been previously dipped in sand. He presses it down, so that it may fill the whole of the cavity, striking off the superfluous clay with a flat wooden rule. The newly-formed brick is then turned out of the mould on to a thin board, somewhat larger than a brick, and it is removed by a boy to a latticed wheelbarrow, and conveyed, covered with fine dry sand, to the *hack*. A handy moulder, working fifteen hours, will mould 5000 bricks. In the hacks, which are eight courses in height, the bricks are arranged diagonally above each other, with a passage between each for the circulation of air round them. The time required for drying in the hacks will, of course, depend on the fineness of the weather; it is but a few days if the season be propitious; and they are then turned and reset wider apart, after which, in about six or eight days, they are ready for the clamp or kiln. If the weather be rainy, the bricks in the hack must be covered with wheat or rye straw; and as they ought to be thoroughly dry before removing to the clamp or kiln, a few are generally selected from different parts, and broken, to ascertain if the operation of drying has been well performed. The moisture arising from bricks when burning is very injurious to their soundness.

1816. In the brickfields about London, bricks are mostly burnt in what are called *clamps*. These are generally oblong in form, and their foundations are made with the driest of the bricks from the hacks, or with common worthless bricks, called place bricks. The bricks for burning are then arranged, tier over tier, to the height assigned to the clamp, according to the quantity to be burnt, and a layer of breeze or cinders, two or three inches deep, is placed between each course of bricks, and the whole, when built up, covered with a thick stratum of breeze. On the western face of the clamp a vertical fireplace is formed, about 3 feet in height, from which flues are driven out by arching the bricks over, so as to leave a space about one brick wide. The flues run in a straight direction through the clamp, and are filled with a mixture of coals, breeze, and wood, closely pressed together. If the bricks are required to be burnt quickly, the flues should not be more than 6 feet apart; but if time do not press, the flues need not be nearer than 9 feet to each other, and the clamp is allowed to burn slowly. It is possible, if required, to burn a clamp in a period of from 20 to 30 days, according to the dryness of the weather.

1817. The kilns which are used for burning bricks are usually 13 feet long, by 10 feet 6 inches in width, and 12 feet in height. The walls are one brick and a half thick, and incline inwards as they rise. A kiln is generally built to contain 20,000 bricks at each burning. The fireplace consists of three arches, which have holes at top for distributing heat to the bricks. These are placed on a lattice-like floor, and first undergo a gentle action of the fire for two or three days, in order to dry them thoroughly. As soon as they thus become ready for burning, the mouth of the fireplace is dammed up with what is called a *shinlog* (which consists of pieces of brick piled against each other, and closed with wet brick earth), leaving above it sufficient room to introduce a faggot. The kiln is then supplied with brushwood, furze, heath, faggots, &c., and the fire is kindled and kept up until the arches assume a white appearance, and flames appear through the top of the kiln. The fire is then slackened, and the kiln gradually cooled. This process of alternately raising and slacking the heat of the kiln is repeated till the bricks are thoroughly burnt, which is usually accomplished in about eight and forty hours.

1818. The practice of steeping bricks in water after they have been burnt, and then again burning them, has been found to have the effect of considerably improving their quality.

1819. There are several sorts of bricks, which may be classed as follows: malms or marl stocks, stocks, place bricks, fire bricks, paving bricks, compass bricks, concave or hollow bricks, and Dutch or Flemish bricks. There are still other varieties; but from their being now but little used, we shall pass them over.

1820. The marl for the marl stock, which is of a bright yellowish uniform colour and texture, is not always to be had, especially in the London districts; in consequence of which, several years ago, it was discovered that chalk mixed in certain portions with loam, and treated in the usual manner, proved an excellent substitute for it. It not only was found to improve the colour, but to impart soundness to the brick; and the practice is now generally adopted about London. At Emsworth, in Hampshire, and also at Southampton, ooze, or sludge, from the sea-shore, containing much saline matter, is used for a similar purpose: these bricks, however, have not the rich brimstone colour of the London malm stock, nor the regular stone-coloured hue of the Ipswich bricks.

1821. The finest marl stocks, which are technically called *firsts*, or *cutters*, are principally used for arches of doorways and windows, quoins, &c., for which purposes they are rubbed and cut to their proper dimensions and form. There is also a red cutting brick, whose texture is similar to the malm cutter, which must not be confounded with the red stock. The next best, which are chiefly used for principal fronts, are called *seconds*: they are not quite so uniform in colour, nor so bright as the last, but are, nevertheless, a handsome and durable brick.

1822. *Stocks* are red and grey, both sorts being equal in texture. The red sort are burnt in kilns. The grey stocks are less uniform in their colour than seconds, and are of rather an inferior quality. They are used for common fronts, and walls.

1823. *Place bricks*, or *peckings*, sometimes also called *sandel*, or *samel bricks*, are those which, having been outermost or furthest from the fire in the clamp, or kiln, have not received sufficient heat to burn them thoroughly. They are, consequently, soft, uneven in texture, and of a red colour. These should never be used in a building where durability is required.

1824. *Burrs* and *clinkers* are such bricks as have been violently burnt, or masses of several bricks run together in the clamp or kiln.

1825. The red bricks derive their colour from the nature of the soil whereof they are composed, which is generally very pure. The best of them are used for cutting-bricks, and are called red rubbers. In old buildings they are frequently found set in putty, and often carved into ornaments over arches, windows, doorways, &c.

1826. *Fire bricks*, so called from their capability of resisting the most violent action of the fire, are of a dark red colour, and of very close texture; they are made about 9 inches long, 4½ inches broad, and 1½ inches thick. The loam of which they are made is yellow, harsh to the touch, and contains a considerable portion of sand. Their quality renders them highly serviceable in furnaces and ovens. The greatest part of those used about London were formerly brought from Hedgerly, a village near Windsor, whence they obtained the name of Windsor bricks. This sort of brick is made also in various parts of Wales, whence they are called *Welsh lumps*.

1827. *Paving bricks* are for the purpose which their name implies, and their dimensions are the same as those of the foregoing sort.

1828. *Compass bricks* are circular on the plan, and are chiefly employed for *steyning*, or walling round wells.

1829. *Concave* or *hollow bricks* are made like common bricks, but hollowed on one side in the direction of their length, and are adapted to the construction of drains and water-courses.

1830. *Dutch clinkers* and *Flemish bricks* vary little in quality; they are exceedingly hard, and are used for the paving of stables, yards, &c., though they are by some objected to, as being too hot for the horses' feet. The former are 6 inches long, 3 inches broad, and 1 inch thick, and are often laid on edge in various fanciful forms, as the herring-bone, &c.

1831. By the 17th Geo. III. cap. 42. all bricks made for sale shall, when burnt, be not less than 8½ inches long, 2½ inches thick, and 4 inches wide. The very limitation is enough to prove the total disregard of the ministers of this country, at all times, to the advancement of the arts. It is scarcely possible to be believed that the statute still continues in force.

1832. Bricks laid in the summer season should be well saturated with water previous to laying; and if the work be left for a day only, the walls should be as carefully covered up as in the winter, for in hot weather the mortar sets too rapidly, and hence the necessary cohesion is destroyed; an evil much aggravated by the dust constantly hanging about the bricks, more especially at that season of the year.

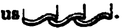
1833. Three hundred and thirty well-burnt bricks may be generally taken as weighing 20 cwt., so that a cubic foot weighs about 125 lbs; and it is found by experiment, that to crush a mass of solid brickwork whose section is 1 foot square, a weight of 300,000 lbs. averdupois must be applied.

1834. Tiles, which in their constituent parts partake much of the nature of bricks, are plates of clay baked in a kiln, and used instead of slates, or other covering of the roofs of houses. The clay whereof tiles are formed will always make good bricks, though the converse does not hold, from the toughness required on account of their being so much thinner than bricks. The common kinds are made of a blue clay, found in many parts about London, though mostly deeper seated than brick earth. The best season for digging it is in September and October, and it should then lie exposed during the winter. It may, however, be turned up in January, and worked in February; and, as in brick, so in tile-making, the more care bestowed on beating and tempering the clay, the better will be the tiles. Tiles are burnt in a kiln constructed on the same principles as the brick-kiln, but with the addition of a cone, having an opening at top round the chamber of the kiln. They require much care in burning. If the fire be too slack, they will not burn sufficiently hard; and if too violent, they glaze, and suffer in form.

1835. *Plain* or *crown tiles* are such as have a rectangular form and plane surface. They should be 10½ inches long, 6¼ inches broad, and ⅝ of an inch thick, according to the statute, and they will weigh each from 2 to 2½ lbs. They are manufactured with two holes in them, through which, by means of oak pins, they hang upon the laths. In using all coverings of this species, one tile laps over another, or is placed over the upper part of the one immediately below; that part of the tile which then appears uncovered is called the gauge of the tiling. If, in plain tiling, the gauge be 6½ inches, about 740 tiles will cover one square, or 100 feet superficial.

1836. *Ridge roof* and *hip tiles* are formed cylindrically, to cover the ridges of houses. They should be 13 inches long, and girt about 16 inches on the outside. Weight about 5 lbs.

1837. *Gutter tiles* are about the same weight and dimensions as ridge tiles, but are for the valleys of a roof. They are now rarely used, their place having been long since supplied by lead.

1838. *Pan* or *Flemish tiles* have a rectangular outline, with a surface both convex and concave, thus . They have no holes for pins, as plain tiles have, but are hung on to the laths by a knot of their own earth on their underside, nearest the ridge, formed when making. They are often glazed, should be 14½ inches long and 10½ inches broad, and weigh from 5 to 5¼ lbs. They are usually laid at a 10 inch gauge, and a square at that gauge will take 170 pan tiles.

1839. The largest sort of paving tiles are 1 foot square and 1¼ inch thick. The next size, called 10 inch tiles, are, in fact, only 9 inches square and 1½ inch thick.

Sect. XI.

LIME, SAND, WATER, AND CEMENT.

1840. Lime has not been found in a native state; it is always united to an acid, as to the carbonic in chalk. By subjecting chalk or limestone to a red heat it is freed from the acid, and the lime is left in a state of purity, and is then called caustic or quicklime, which dissolves in 680 times its weight of water. It is not our intention here to enter into any account of either of the theories relative to the formation of lime, facts being of more importance to the architect in its employment than the refined fancies of the scientific chemist. The calcareous minerals are mostly distinguished by their effervescing with and dissolving in an acid, as also by their being easily scratched or cut with a knife. In respect of the lime obtained from chalk, Dr. Higgins (in his work on calcareous cements, Lond. 1780) says, " It should be observed, that the difference between chalk lime and the lime obtained from the various limestones, chiefly consists in the greater retention or expulsion of the carbonic acid gas contained in them."

1841. An account of the stone from which lime may be obtained in the different counties of England would unnecessarily extend this article; we shall, therefore, after observing that the use of marble for burning to lime would be too expensive, state the varieties of limestone as, 1. the compact; 2. the foliated; 3. the fibrous; and, 4. the peastone. The compact limestones are of various colours, in hues inclining to grey, yellow, blue, red, and green, and to a smoky sort of colour besides. It is usually found massive, often compounded with extraneous fossils, particularly shells. Its internal appearance is dull, the texture is compact, the fracture small, fine, and splintery; fragments indeterminately angular, more or less sharp-edged; semihard, sometimes soft, brittle, and easily frangible. Specific gravity varies from 2500 to 2700, and it is composed of lime, carbonic acid, and water, mostly with a portion of argyll and oxide of iron, and sometimes of inflammable matter.

1842. The foliated limestones are such as calcareous spar, statuary marble, &c.; the fibrous limestones, such as satin spar; and the pea stone, another species of spar. It may be remarked, that the various sorts of marble, chalk, and limestone may be divided into those which are nearly pure carbonate of lime, and those containing in addition from one twentieth to one twelfth of clay and oxide of iron. " Though the best limestones are not such as contain the greatest quantity of clay, yet," observes Mr. Smeaton, " none have proved good for water building, but what, on examination of the stone, contained clay; and though, he continues, " I am very far from laying down this as an absolute criterion, yet I have never found any limestone containing clay in any considerable quantity, but what was good for water works, the proportion of clayey matter, being burnt, acting strongly as a cement; and limes of this kind all agree in one more property, that of being of a dead frosted surface on breaking, without much appearance of shining particles.

1843. Among the strongest limes, and such as will set under water, those most in use in the metropolis and its neighbourhood are procured from Dorking, Merstham, and the vicinity of Guilford. The most celebrated in the West of England is the blue lias of Somersetshire, and in the north that about the county of Sunderland, whereof very large quantities are exported to Scotland. The Dorking and other limes of that part are burnt from a chalk formation so extremely hard that it is quarried even for the purposes of masonry. Those of Merstham particularly are obtained from an indurated chalk marle (clay and chalk) which is so hard that it partakes of the nature of stone. The known property of the lias formation for setting under water renders it an invaluable material in the hands of the architect. In the neighbourhood of Bath it is called Bath brown lime, and when prepared for cementing with metallic cement, is said to be *wind slacked;* that is, after burning, it is placed in roofed sheds open at the sides, and the atmosphere is thus introduced to act upon it. The colour of the lias, previous to burning, is blue; after it has passed the kiln, it is of a rich brown colour. No accurate analysis of this has come to our knowledge; but we have understood that specimens have been analysed, containing as much as 90 per cent. of carbonate of lime, the residuum probably consisting of alumen and iron. The magnesian limestone of Sunderland lies north-west of the red sandstone. In the vicinity of South Shields, in the county of Durham, the formation becomes extensive, and is to be traced to the Tees below Winston Bridge. The Whitby quarry near Callercoats has been described in the 4th volume of the *Geological Transactions.* The Sunderland limestone is of a bronze colour, and from containing inflammable matter, does not require so much fuel to convert it into lime.

1844. Before limestone is burnt it seems to possess no external character by which a distinction can be made between the simple and the argillo-ferruginous limestones; whatever the colour of the former, they become white when burnt, whilst the latter partake more or less of a slight ochrey tint. Brown lime is the most esteemed for all sorts of cements, whilst for common purposes, the white sorts, which are more abundant, are sufficiently useful. In England, the limestones in colour generally incline to a red or blue, and those which are found firm, weighty, and uniform in texture are to be preferred. Masses broken from large rocks and beds on the sides of hills, and those when newest taken and deepest dug, are most to be valued.

1845. The process of analysing limestones is so eminently useful to all concerned in building, that we cannot refrain from transcribing the method used by Smeaton in his own words. "I took about the quantity of five pennyweights (or a guinea's weight) of the limestone to be tried, bruised to a coarse powder, upon which I poured common aquafortis, but not so much at a time as to occasion the effervescence to overtop the glass vessel in which the limestone was put, and added fresh aquafortis after the effervescence of the former quantity had ceased, till no further ebullition appeared by any addition of the acid. This done, and the whole being left to settle, the liquor will generally acquire a tinge of some transparent colour; and if from the solution little or no sediment drops, it may be accounted a pure limestone (which is generally the case with white chalk and several others), as containing no uncalcareous matter in its composition. When this is well settled, pour off the water, and repeatedly add water in the same way, stirring it, and letting it settle till it becomes tasteless. After this, let the mud be well stirred into the water, and without giving it time to settle, pour off the muddy water into another vessel, and if there is any sand or gritty matter left behind (as will frequently be the case), this collected by itself will ascertain the quantity and species of sabulous matter that entered into the texture of the limestone. Letting, now, the muddy liquor settle, and pouring off the water till no more can be got without an admixture of mud, leave the rest to dry, which, when of the consistence of clay, or paste, is to be made into a ball, and dried for further examination."

1846. The loss of limestone by burning is about four ninths of its weight, shrinking, however, but little. When completely burnt, it falls freely, in slaking, into powder, and then occupies about double its previous bulk.

1847. There are many sorts of kilns for burning limestone, varying in form with the fuel employed, and the combination of the process itself with some other, such, for instance, as making coke, and sometimes bricks. The limestone, however, is generally burnt in kilns whose plans are circular and section resembling an inverted truncated cone; of late more frequently made spheroidal. The heat is in either case obtained from a fireplace under the limestone, which rests on bars, that can, when the kiln is a perpetual one, egg-formed, or a draw kiln, be removed, to let out the lime as it is burnt, whose deficiency, on extraction, is supplied by fresh stone at the top of the kiln. *Sod kilns* are sometimes used for lime burning. These are formed by excavating the earth in a conical form, and then building up the sides as the earth may require. In using these, the limestone is laid in with alternate layers of fuel to the top of the kiln, and the top being covered with sods, so as to prevent the heat from escaping, the fire is lighted, and the process effected. The lime is not removed till it is thoroughly cool. This mode is a tedious operation, and, because of the quantity of fuel consumed, far from economical. In the common lime-kiln, the fire is never suffered to go down, but as the well-burnt lime is removed, fresh lime is supplied. There is a species of kiln called a flame-kiln, in which the calcination is effected with peat. In this kiln the process of burning bricks is carried on at the same time.

1848. Lime burners have made the important observation, that the quantity of stone calcined and the quantity of fuel expended depend on the quality of the fuel. Hence the kiln is constructed with reference to the fuel, rather than to the nature of the stone to be calcined. Limestone, taking an average time, requires burning about sixty hours to reduce it to lime, when the heat is strong and well regulated: but of course no general rule can be laid down, as different species will require different periods of time. The principal object to be accomplished, is the expulsion of the carbonic acid gas which enters into its composition.

1849. That lime is generally most esteemed which heats most in slaking, and slakes the quickest, falling into a fine powder. If there be among it coarse unslakeable lumps called *core*, that will not pass through the screen, either the stone has not been sufficiently burnt, or it originally contained extraneous matter; which not only indicates defect in quality, but that it will be, as they more or less abound, more costly in use.

1850. From the experiments of Mr. Smeaton and of Dr. Higgins, it is sufficiently proved that, when chalk or stone lime is equally fresh when used, the cementitious properties of both are nearly, if not quite, equal; but from the circumstance of quicklime absorbing carbonic acid more or less in proportion as its texture is solid or spongy, so it gradually parts with its cementing nature, becoming at length altogether unfit for the purposes of mortar. Thus, though each of the sorts may be equally good, if properly burnt and quite fresh from the kiln, yet from the chalk lime so much more easily and rapidly taking in the carbonic acid than stone lime does, it is not so fit for general use; and, indeed, now the metropolis is so well supplied with the harder chalk and stone limes, there is no excuse for its use, and it should in sound building be altogether banished.

1851. The following table, from Smeaton, contains a list of the limestones he examined on the occasion of building the Eddystone Lighthouse.

Species of Stone.	Proportion of Clay.	Colour of the Clay.	Reduction of Weight by burning.	Colour of Brick made of such Clay.
Aberthaw, on the coast of Glamorganshire - -	$\frac{3}{23}$	Lead colour	4 to 3	Grey stock brick
Watchet, small sea-port in Somersetshire - -	$\frac{2}{23}$	Do.	4 to 3	Light colour, reddish hue.
Barrow, Leicestershire -	$\frac{3}{14}$	Do.	3 to 2	Grey stock brick.
Long Bennington, a village in Lincolnshire - -	$\frac{3}{22}$	Do.	- -	Dirty blue.
Sussex Church, near Lewes in Sussex - - -	$\frac{2}{16}$	Ash colour	3 to 2	Ash colour.
Dorking in Surrey - -	$\frac{1}{17}$	Do.		
Berryton grey lime, near Petersfield, Hants - -	$\frac{1}{12}$	Do.		
Guilford, Surrey - -	$\frac{2}{19}$	Do.		
Sutton, Lancashire - -	$\frac{3}{16}$	Brown		

1852. In forming mortar from the lime, it must, when slaked, be passed through a sieve leaving only a fine powder, an operation usually performed with a quarter inch wire screen set at a considerable inclination to the horizon, against which the lime is thrown with a shovel after slaking. That which passes through is fit for use; the core falling on that side of the screen against which the lime is thrown, being entirely rejected for the purpose in question, though it is an excellent material for filling in the sides of foundations under wood floors where they would otherwise be next the earth, and the like. The sifted or screened lime is next to be added to the sand, whose quantity will vary as the quality of the lime, of which we shall presently speak. In making mortar, there is no point so important as respects the manufacture itself, as the well tempering and beating up the lime with the sand after the water is added to them. In proportion, too, as this is effectually done, will a small proportion of lime suffice to make a good mortar. The best mode of tempering mortar is by means of a pug-mill with a horse-track similar to the clay-mills used for making bricks. But if such cannot be had, the mortar should be turned over repeatedly, and beaten with wooden beaters, until it be thoroughly mixed. That this process should be carefully performed, will appear of the more importance when it is considered that it thereby admits a greater proportion of sand, which is not only a cheaper material, but the presence of it renders a less quantity of water necessary, and the mortar will consequently set sooner: the work, too, will settle less; for as lime will shrink in drying, while the sand mixed with it continues to occupy the same bulk, it follows that the thickness of the mortar beds will be less variable. It may be taken, indeed, as an axiom, that no more lime is necessary than will surround the particles of sand.

1853. In most of the public works executed in Great Britain of late years, the proportion of lime to sand is as 1 to 3; and when the former is made from good limestone, the sand is by no means too much in proportion. Dr. Higgins, in his experiments, has gone so far as to recommend 7 parts of sand to 1 of lime, which, for mortar, is perhaps carrying the point to the extreme.

1854. Various additions are made to mortar, in order to increase its hardness and tenacity; such as coal and wood ashes, forge scales, roasted iron ore, puzzuolana, and the like. The *cendre de Tournay* is used in the low countries. This is an article procured from the lime-kilns bordering the Scheldt. The lime of this district contains a considerable portion of clay mixed with iron; and the pit-coal with which it is burnt contains a large quantity of an argillaceous schist, impregnated with iron. After the lime is taken out of the kilns, there remains the cendre, about one fourth of which consists of burnt lime-dust, and three fourths of coal-ashes. This material is sprinkled with water to slack the lime, and well mixed together, and put into a proper vessel and covered over with wet earth. In this state it is kept for a considerable time; and when taken out, and strongly beaten up for half an hour with an iron pestle in a wooden mortar or trough, it is reduced to a soft pasty consistence; it is then spread out for several days in a shady place, and the operation of beating repeated: the oftener this is done the better, except it should become unmanageable from being too much dried. In a few minutes, this cement, when applied to brick or stone, adheres so firmly that water may be immediately poured over it; and if kept dry twenty-four hours, it afterwards receives no injury even from the most violent action of a flowing stream.

1855. In London, a blue mortar is used for covering parts of buildings much exposed to the weather; and if prepared with similar labour and attention, it might, in a great degree, possess the valuable properties of the mortar of the Scheldt, just mentioned.

1856. Common ashes mortar is made by mixing two bushels of newly slacked lime and three bushels of wood ashes, which, when cold, must be well beaten, in which state it is usually kept for a considerable time, and indeed it improves by keeping if beaten two or three times previous to using it. This mixture is superior to terras mortar in resisting the alternate effects of dryness and moisture, but not comparable with it under water.

1857. Mr. Smeaton discovered, by a course of experiments, that the scales (grey oxide of iron) that fly off under the forge hammer from red hot iron, pulverised, sifted, and mixed with lime, form an admirable cement, equal to puzzuolano. He found, in pursuing his experiments, that roasted iron ore produced an effective water cement, by using a greater proportion of it than either terras or puzzuolano. Equal quantities of iron scales and argillaceous lime, with half the quantity of each of these of sand, produced a cement in every respect equal to terras mortar. If pure carbonate of lime be used, equal parts of each of the ingredients ought to be incorporated. We do not think it necessary here to give any account either of Loriot's cement, nor that proposed by Semple: neither are to be depended on: indeed the first, as a water cement, is of inferior utility, and very little better than common mortar dried before the admission of water upon it.

1858. *Sand* should by all means, if possible, be procured from a running clear stream, in preference to that obtained from pits. It is cleaner, and not so connected with clayey or muddy particles. About the metropolis it is the practice to use (and an admirable material it is) the sand of the Thames procured from above London Bridge. This sand has acquired a deserved reputation among the architects and builders of the capital. It contains, however, a vast portion of heterogeneous matter, such as calcareous fossil, quartzose, and flint sands, particles of coal alluvium, and much iron. The sharp drift sand of the Thames should therefore, before mixing with the lime, be well screened and washed.

1859. If pit sand only can be procured, it should be repeatedly washed, to free it from the earthy and clayey particles it contains, until it becomes bright in colour, and feels gritty under the fingers. When the architect is obliged to use sea sand, it must be well washed in fresh water until the salt is entirely removed; otherwise the cement for which it is used will never dry.

1860. *Grout*, or *liquid mortar*, is nothing more than common mortar mixed with a sufficient quantity of water to make it fluid enough to penetrate the interstices and irregularities of the interior of brick walls, which common mortar will not reach. The mortar whereof it is made will bear 4 of sand to 1 of lime, but it should be thoroughly beat. It may be kept a little longer, whereby its quick setting will be facilitated.

1861. *Water*. Dr. Higgins recommends the use of lime water for the composition of mortar. This, in practice, would be impossible. The water used, however, for the incorporation of the lime with the sand should be soft and pure. The screened lime and sand being shovelled together, as little water as possible is added, after which the chafing and beating, or tempering in a pug-mill, takes place.

1862. Under this section, notice must be taken of a compound of ballast or stone chippings and lime mixed together, which has received the name of *concrete*, from the speedy concretion that takes place between the different particles whereof it is composed. If, however, *gallots* or small stone chippings are used, sand in a large proportion to the lime must be used. The use of concrete was well known at an early period, and is by no means, therefore, a discovery of modern days. Wherever the soil is soft, and unequal for the reception of the foundations of a building, the introduction of concrete under them is an almost infallible remedy against settlement. The Thames ballast, commonly used for concrete, is a mixture of sand and small stones. With this, and lime in the proportion of never less than 4 to 1, and never properly exceeding 9 to 1, of stone lime, or such as is known to set hard in water, a mixture is made. The lime is generally used in powder, and the whole being shovelled together, it is wheeled in barrows to a stage over the spot where it is to be used, and let fall into the trench dug out for the reception of the foundation. The greater the height the concrete is made to fall, the sounder and stronger it becomes. It must always be recollected that no more lime is necessary than with the thinnest coat to surround the particles of the ballast, and that therefore the size of the pebbles or stones should influence the quantity of the lime. As the ground is more or less to be trusted, the thickness of the concrete must be regulated; when used on the best ground, a foot in thickness will be sufficient; while on the worst, as many as four feet or more may be required. The upper surface being levelled, it is usual to lay on it a tier of Yorkshire stone landings, for the reception of the brick-work or mason's work: in some cases, after carrying the wall a certain height, a second tier of landings has been introduced. When the soil is watery, no water should be put to the concrete, but the ballast and lime merely mixed and tumbled in. The stones or pebbles forming a portion of the concrete should never exceed the size of a hen's egg.

1863. The principal cements used in England are those generally known by the names of Parker's, Atkinson's, and Hamelin's mastic. The first named, also called Roman cement, is manufactured principally from stone found in the Isle of Sheppey, and at Harwich, being *septaria* from the London clay, and properly classed among the limestones indigenous to this country. It consists of ovate or flattish masses of argillaceous limestone arranged in nearly horizontal layers, chiefly found imbedded in the London clay. The substance being coated with a calcareous spar or sulphate of barytes, forms the basis of the cement. That now in use we do not think at all equal to the material originally employed. Thirty years ago it was possible to use it in the depth of winter; which, we apprehend, would be a hazardous thing to do with the cement at present made. Whether the inferiority arise from adulteration, bad manufacture, or the material being worse, we cannot pretend to say; we, however, do not believe that it arises from the badness of the raw material. If this cement be of extremely good quality, 2 parts of sand to 1 of the cement may be used. The cement itself is a fine impalpable powder; yet when wetted it becomes coarse, and, unless mixed with great care, it will not take a good surface. When mixed with the sand and water, it sets very rapidly; it is necessary, therefore, to avoid mixing much at a time, or a portion will be lost. The colour of this cement, when finished, is an unpleasant dark brown, and the surface requires frequent colouring. The great value of Parker's cement is its being impervious to water almost the moment it is used; hence it becomes highly serviceable on the backs of arches under streets, for the lining of cisterns, and for carrying up in it, or coating with it, damp walls on basement stories. It will not resist fire so well; and it should therefore never be employed for setting grates, ovens, coppers, or furnaces.

1864. Atkinson's cement is a good material, preferable in colour to the last named, but, as we think, inferior in quality. It takes a much longer time to set than Parker's cement, than which it absorbs more moisture. It answers well enough in dry situations.

1865. Hamelin's mastic cement, which, though patented of late years, is an invention of P. Loriot, a century old, is one in which the medium for mixing is oil instead of water. It is much more difficult to use than the other cements, and requires great experience and care in using. A coat of it should never exceed one quarter of an inch in thickness; hence it is totally unfit for working mouldings in the solid. In the metropolis it is generally used in a very thin coat over a rough coat of Roman cement, in which case it is rarely more than an eighth of an inch thick. Thus used, it not only presents a beautiful surface, but is extremely durable.

1866. The stones whereof the *Dutch tarras* is made are found in the neighbourhood of Liege, and also, we believe, at Andernach on the Rhine, from the size of a pea to that of a middle-sized turnip. From their being brought down the rivers to Holland the cement has been called Dutch; the only operation they undergo in that country is the reduction of them to a coarse powder by means of mills. They are beaten by iron-headed stampers on an iron bed till they will pass through a sieve whose wires are about one eighth of an inch apart. This cement is sent from Holland in casks.

1867. *The Puzzolana*, or *terra Puteolana* of the Romans, which, as well as the last-named cement, has been almost if not quite superseded by the introduction of the Roman cement, is brought from Civita Vecchia. Its name is however derived from Puzzuoli, where it is principally found, though produced in other parts of Italy, in the neighbourhood of extinct volcanoes. It suddenly hardens when mixed with one third of its weight of lime and water, forming a cement more durable under water than any other. Bergman found 100 parts of it to contain 55 to 60 parts of siliceous earth, 20 of argillaceous, 5 or 6 of calcareous, and from 15 to 20 of iron; this last constituent is considered to be the cause of its property of hardening under water. The iron decomposes the water of the mortar, and thus in a very short time a new compound is formed. According to Vitruvius, when used for buildings in the water, 2 parts of Puzzolana were mixed with 1 of mortar.

Sect. XII.

GLASS.

1868. Glass is a combination of silex with fixed alkali, generally soda. The mixture when calcined receives the name of *frit*, which, after the removal of all its impurities, is conveyed to the furnace and melted in large pots or crucibles till the whole mass becomes beautifully clear, and the dross rises to the top. After being formed into the figures required, it is annealed or tempered by being placed in an appropriate furnace. The fineness depends on the purity and proportion of the ingredients. An extremely fine crystal glass is obtained from 16 parts of quartz, 8 of pure potash, 6 of calcined borax, 3 of flake white, and 1 of nitre. The specific gravity of glass is about 2600; of French plates, 2840; of English flint glass, 3320. Glass is extremely elastic, and less dilatable by heat than metallic substances.

1869. *Crown glass* is the best sort of window glass, differing from flint glass in its containing no lead nor any metallic oxide except manganese, and sometimes oxide of cobalt, in minute portions, for correcting the colour, and not as a flux. It is compounded of sand, alkali, either potash or soda, the vegetable ashes that contain the alkali, and generally a small portion of lime. To facilitate fusion, a small dose of arsenic is frequently added. Zaffre or oxide of cobalt, in the proportion of 1 ounce for 1000 pounds, is added, to correct the colour; but when the sand, alkali, and lime are very fine, and no other ingredients are used, zaffre is not required. In London were formerly made two sorts of crown glass. The Ratcliffe crown glass, which was the cheapest and best, whereof 24 tables went to the case; each table being 3 feet 6 inches diameter. The Lambeth glass was of a darker and greener colour. From the great disadvantage of manufacturing window glass where fuel is so dear, we have not now left a glass-house in the metropolis. Bristol and Newcastle are now the chief seats of its manufacture.

1870. The manufacture of common window glass is conducted differently from that of flint glass articles, the object being to produce a large flat thin plate of glass, which is afterwards by the glazier's diamond cut into the requisite shape. It is blown in circular plates, varying from 3 feet 6 inches to 4 and 5 feet diameter, and the process is as follows: — The workman, having a sufficient mass of melted metal on his blow-pipe, rolls it on an iron plate, and then, swinging it backwards and forwards, causes it by its own gravity to lengthen into a cylinder, which is made and brought to the required thinness by blowing with a fan of breath, which persons accustomed to the work know how to manage. The hollow cylinder is then opened by holding it to the fire, which, expanding the air confined within it (the hole of the blow-pipe being stopped), bursts it at the weakest part, and while still soft it is opened out into a flat plate by the centrifugal force; and being disengaged from the rod, a thick knob is left in its centre. It is then placed in a certain part of the furnace to undergo the process of annealing. When the table is cut for use, the centre part in which the knob remains is called *knob-glass*, and is used only for the commonest purposes.

1871. Tables are now made of such a size that squares may be procured 33 inches by 25, and even larger.

1872. The three qualities of glass in common use are called best, second, and third; the last is of a very green hue, and only used for inferior buildings. These are all of them sold by the *crate*, at the same price, the difference being made up by varying the number of the tables contained in it. Thus a crate of best crown glass contains twelve tables; of seconds, a crate contains fifteen; and of thirds, eighteen tables.

1873. German sheet glass was formerly much in demand here; but the great competition that has lately grown up in the manufacture of English plate glass, which has been much lowered in price, has brought this last into very extended use; and we seem likely to rival, if not surpass, the French in the manufacture of it.

1874. *Plate glass* is so called from its being cast in large sheets or plates. Its constituent parts are white sand, cleansed with purified pearl-ashes, and borax. If the metal should appear yellow, it is rendered pellucid by the addition, in equal small quantities, of manganese and arsenic. It is cast on a large horizontal table, and all excrescences are pressed out by passing a large roller over the metal. To polish it, it is laid on a large horizontal block of freestone, perfectly smooth, and then a smaller piece of glass, fastened to a plank of wood, is passed over the other till it has received a due degree of polish. For the purpose of facilitating the process, water and sand are used, as in the polishing of marble; and, lastly, Tripoli, smalt, emery, and putty, to give it lustre; but to give it the finishing polish the powder of smalt is used. Except in the very largest plates, the workmen polish their glass by means of a plank having four wooden handles to move it, and to this plank a plate of glass is cemented.

1875. Pliny gives the following account of the discovery of manufacturing glass, which was well known in Aristotle's time, 350 B. C. "A merchant vsesel, laden with nitre or fossil alkali, being driven on the coast of Palestine, near the river Belus, the crew accidentally supported the kettles on which they dried their provisions on pieces of the fossil alkali; the sand about it was vitrefied by its union with the alkali, and produced glass." Though, according to Bede, artificers skilled in making glass were brought into England in 674, glass windows were not generally used here till 1180, and were for a considerable time esteemed marks of great magnificence.

SECT. XIII.

ASPHALTE.

1876. Asphalte is a calcareous bituminous substance, latterly introduced into this country chiefly for pavements, which (we speak of that of Seyssel) was first discovered at Pyrimont, a mountain on the eastern side of the Jura, and on the right bank of the river Rhone, one league north of the town of Seyssel, and has obtained its name from its intimate combination of asphaltum and other bituminous substances with pure carbonate of lime. The mountain is composed of blocks of stone, which being conveyed to the places where intended to be used, are there reduced to powder, 90 parts whereof are placed in a cauldron with 10 parts of mineral pitch, and exposed for a considerable time to a heat of 600 degrees of Fahrenheit. The substance thus obtained is used in a state of fusion, and in a few minutes after being laid down, it becomes so hard that it is, with a temperature of more than 100 degrees of Fahrenheit, susceptible of no impression. It is, however, said, nevertheless, to retain an elasticity, by which it adapts itself to all the action which, for its varied purposes, it is required to undergo. It has long been in use in the south of France, the footway of the Pont Moraud, a much frequented bridge, at Lyons, having been paved with it in 1827, and being, we believe, still in a very sound state. At Fort l'Ecluse, in the vicinity of the mountain, a small building covered with it has withstood the cold of forty Swiss winters, and is said still to continue in a perfect state of repair. For the last fourteen years, it has been occasionally used to cover the roofs of buildings in Paris, a purpose to which, for many reasons, we would not recommend its application in this country, though for a vast number of other objects it seems admirably adapted, such as foot pavements in streets, vaults, kitchens, passages, and all places where it is essential to exclude moisture, for barn floors, piggeries, farm yards, and the like.

1877. It is said (we have had no experience of it) to form with gravel a good concrete, where the soil is doubtful for bearing weight, and that it may be used as a cement for foundations, instead of mortar. It appears, from experience, not to be inflammable, a roof at Bordeaux adjoining a large house that was burnt there not having suffered, though all sorts of ignited materials fell upon it.

1878. In the years 1832, 1833, and 1834, the asphalte appears to have been successfully employed in constructing the fortifications at Vincennes, and also in the military works at Douay, Besançon, Bourbonne les Bains, Grenoble, and Lyons.

1879. Among the arguments used by the proprietors of the asphalte of Seyssel, here, where it is now, we believe, patented, over all the other sorts competing with it, are the following: — that the carbonate of lime and bitumen being combined in it by nature, it is *absolutely perfect* (these are their words), while in every artificial imitation the calcareous particles are merely enclosed by pitch; that the chalk is, consequently, unamalgamated, and the composition susceptible of the extremes of heat and cold. Another point of advantage whereon they insist is, that the asphalte of Seyssel consists in the large proportion of the calcareous matter to the bitumen, being about 83 to 17; while the combination effected by artificial means has never exceeded 60 of chalk to 40 of bitumen. The quantity, they say, of bitumen to be used should be the smallest that will hold the chalk in combination; and that therefore the manufactured article contains more than it should, and will consequently expand in summer and contract in winter.

1880. Making great allowances for the self-interest which the prospectus of every speculating company exhibits, we are, nevertheless, inclined to think that the asphalte of Seyssel is a valuable and important material for many building purposes, and have no doubt that it will be extensively used in this country. At present the price is high, as well from the cost of the material itself as from the necessity of procuring a solid foundation of concrete, or some other substance, whereon to lay it securely. There are several spots in the metropolis, as at Whitehall, for instance, where it has been used for foot pavements; but for other purposes we must abstain from recommending its application until experience shall justify the architect in its employment.

CHAP. III.

USE OF MATERIALS.

Sect. I.

FOUNDATIONS AND DRAINS.

1881. In the previous chapter, we have enumerated the principal materials used in building; we shall now proceed to show how those materials may be most advantageously employed; but we shall not, in the various branches of the practice, again touch on the materials themselves, which have been, we conceive, already sufficiently described. But previous to entering upon the different branches of practical building, we think it right to submit to the reader a few observations on that most important of all considerations — a due regard to the security of the foundations on which a building is to stand, as a preliminary to the works of the bricklayer and mason, as the case may be. No advance or improvement has been made in this branch of architecture, as a science, since the time of the ancients. The advice of Vitruvius may still be followed with safety. In England, the recent introduction of concrete has superseded the use of wood under walls in the earth; and piles are now quite exploded, except for the piers of bridges and other situations in which they can constantly be kept wet.

1882. The best soils for receiving the foundations of a building are rock, gravel, or close-pressed strong sandy earth; "but," says L. B. Alberti, "we must never trust too hastily to any ground, though it may resist the pick-axe, for it may be in a plain, and be infirm, the consequence of which might be the ruin of the whole work. I have seen a tower at Mestre, a place belonging to the Venetians, which, in a few years after it was built, made its way through the ground it stood upon, which, as the fact evinced, was a loose weak soil, and buried itself in earth up to the very battlements. For this reason, they are very much to be blamed who, not being provided by nature with a soil fit to support the weight of an edifice, and lighting upon the ruins or remains of some old structure, do not take the pains to examine the goodness of the foundation, but inconsiderately raise great piles of building upon it, and out of the avarice of saving a little expense, throw away all the money they lay out in the work. It is, therefore, excellent advice, the first thing you do, to dig wells, for several reasons, and especially in order to get acquainted with the strata of the earth, whether sound enough to bear the superstructure, or likely to give way." It is important, previous to laying the foundations, to drain them completely, if possible, not only from the rain and other water that would lie about, but from the land water which is, as it were, pent up in the surrounding soil. In soft, loose, and boggy ground, the use of concrete will be found very great; and in these soils, moreover, the width and depth it should be thrown in, should, as well as the lower courses of the foundation, be proportioned inversely to the badness of the soil. Clay of the plastic kind is a bad foundation, on account of the continual changes, from heat and moisture, to which it is subject, and which often cause it so to expand and contract as to produce very alarming settlements in a building. The best remedy against this inconvenience is to tie the walls together by the means of chain plates, buried in the centre of the footings, and on the top of the landings that rest on the concrete; these plates to be, of course, connected at the returning angles, so as to encompass the whole building. In these cases, the clay must be excavated to make room for the concrete. This will be found an effectual remedy in clay soils.

1883. If the soil be a sound gravel, it will want little more than ramming with heavy rammers; and if the building be not very heavy, not even that.

1884. Where vaults and cellars are practised, the whole of the soil must, of course, be excavated; but where they are not required, trenches are dug to receive the walls, which, in both cases, must be proportioned in strength to the weight of the intended superstructure and its height. In general terms, we may direct the depth of foundations to be a sixth part of the height of the building, and the thickness of the walls twice that of those that are raised upon them. Care must be taken that that which is to receive the footings of the walls be equable; otherwise, where external and internal walls are connected together, the former, being the heaviest, may settle more than the latter, thereby causing fractures, which, though not, perhaps, dangerous, are extremely disagreeable in appearance. The lower courses, which are called the footings of the wall, are often laid dry; and, perhaps, at all events, a sparing use of mortar in a spot loaded with the greatest pressure should be preferred. If the footings be of stone, very particular attention should be bestowed on placing the stone in the courses in the same direction or bed as it lay in the quarry, to prevent its splitting.

1885. In foundations where, from columns or small piers pressing upon particular parts, there would be a liability, from uneven bearing, to partial failure, it has been the practice, from a very early period, to turn inverted arches (see *fig.* 615.) to catch on their springing the weight to be provided against, by which means such weight is equally distributed throughout the length of the foundation. " Standing thus," says our master Alberti, " they (the columns or weights) will be less apt to force their way into the earth in any one place, the weight being counterpoised and thrown equally on both sides on the props of the arches. And how apt columns are to drive into the ground, by means of the great pressure of the weight laid on them, is manifest from that corner of the noble temple of Vespasian that stands to the north-west; for, being desirous to leave the public way, which was interrupted by that angle, a free and open passage underneath, they broke the area of their platform, and turned an arch against the wall, leaving that corner as a sort of pilaster on the other side of the passage, and fortifying it as well as possible, with stout work, and with the assistance of a buttress. Yet this, at last, by the vast weight of so great a building, and the giving way of the earth, became ruinous."

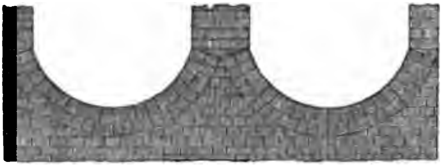


Fig. 615.

1886. It is most important, when the walls are raised on the foundations, and brought up a little above the level of the earth, to take care that the earth, most especially if moist, should not lie against them; for if walls, before they are dry and settled, imbibe moisture, they rarely ever part with it, and thence gradually impart rot to the timbers throughout the house. In all buildings, it is an object to have a second thin wall outside the basement walls, so as to leave between it and them a cavity for the circulation of the air, such cavity being technically called an *air-drain*. This is in all cases desirable, but in moist and loose soils it is essentially necessary for the durability of the building, as well as for the health of those who are to dwell in it.

1887. We, perhaps, might have more properly spoken first of the subject of drainage and sewers, whereof it now becomes our duty to give some information, inasmuch as before a brick or stone of any building be laid, the architect neglects his duty if he has not provided for perfect drainage in the lowest parts of the structure. This must not be by the aid of a small stagnant tank, called a *cesspool*, often the cause of much disease in a family; but by means of a drain into some running stream at a distance from the building, or, if that be not practicable, into some far removed pond, whose exhalations shall not be blown by the prevalent winds of the spot back upon the place where they were generated, in a different form. Neither does the health alone of the family whose comfort is to be provided for, demand this consideration of drainage; for the durability of the structure is quite as much involved in good drainage as is the health of the family whose dwelling-place the house is to become: hence we are the more earnest in pressing the point. In cities, the architect cannot always accomplish this most important object to the extent of his desire; but in the country, he is unpardonable if he neglect so necessary a provision. In London and its suburbs, the laying down of efficient sewage has been gradually proceeding; and in half a century, should it proceed at the same rate that it has during the last fifteen years, we apprehend that there will be no city in Europe possessing so good a drainage.

1888. The main drain necessary for the service of the largest house (we suppose the case of one in the country), if the fall given it be even but moderate, requires no very large dimensions. When we recollect that a small river, draining a very considerable tract of country, is often in its section only 8, 9, or 10 feet superficial, it will easily be conceived that the surplus from, and rain water falling on a mansion, is a quantity, even at the most pressing times, requiring little area of discharge to free the place from damp. There are few cases in which the largest mansion would require, for its main branch of drainage, an area of more than 5 feet, which would be given by a sewer or drain 2 ft. by 2 ft. 6 in., supposing its section to be that of a parallelogram; but of course, where the fall permits, there is no objection to larger dimensions. It will be hardly necessary to recommend that drains should, as well for their durability as on other accounts, be constructed with curved bottoms. It is surprising that some (at least one) commissions of sewers about the metropolis should still persist in constructing their principal drains with flat bottoms, offering an additional impediment, by increased friction, to the more rapid discharge of the water. Thus, for instance, let us take the lower parts of two drains whose running depth of water is 1 foot, one whereof is formed with a semicircular bottom, 2 feet wide; the area of the column of water will therefore be 1·5708, and the length of the half curve will be 3·1416. To obtain, with one foot depth of water, the same area in a drain whose bottom is flat and sides upright, we must have the width 1·5708, and the sum of the three sides touched by the water will be 3·5708. Then 3·5708 − 3·1416 = ·4292 represents roughly the difference of friction or impediment in favour of the semicircular bottom in the case stated, nearly $\frac{13}{100}$ of the power being lost by the use of a flat bottom.

Sect. II.

BRICKLAYING AND TILING.

1889. Bricklaying, or the art of building with bricks, or of uniting them by cement or mortar into various forms, includes, in the metropolis, and mostly in the provinces, the business of walling, tiling, and paving with bricks or tiles, and sometimes plastering; but this last is rarely, if ever, undertaken by the London bricklayer; though in the country the trades of bricklaying and plastering are usually united, and not unfrequently that of masonry also. The materials used have been described in a previous part of the work, to which the reader is referred (1811. *et seq.*).

1890. The tools used by the bricklayer, who has always an attendant labourer to supply him with bricks, mortar, &c., are — 1. A *brick trowel*, for taking up and spreading the mortar, and also for cutting the bricks to any required length. 2. A *hammer*, for cutting holes and chases in brickwork. 3. The *plumb rule*, being a thin rule, 6 or 7 inches wide, with a line and plummet swinging in the middle of it, in order to ascertain that the walls are carried up perpendicularly. 4. The *level*, which is about 10 or 12 feet long, with a vertical rule attached to it, in which a line and plummet are suspended, the use whereof is to try the level of the walls at various stages of the building as it proceeds, and particularly at the window cills and wall plates. 5. The *large square*, for setting out right angles. 6. The *rod*, for measuring lengths, usually 5 or 10 feet long. 7. The *jointing rule*, about 8 or 10 feet long, as one or two bricklayers are to use it, and 4 inches broad, with which they *run* or mark the centre of each joint of the brickwork. 8. The *jointer*, which is of iron, shaped like the letter S. 9. The *compasses*, for traversing arches and vaults. 10. The *raker*, a piece of iron having two knees or angles, dividing it into three parts at right angles to each other, the two end parts being pointed and equally long, and standing upon contrary sides of the middle part. Its use is to rake out decayed mortar from the joints of old walls for the purpose of replacing it with new mortar, or, as it is called, *pointing* them. 11. The *hod*, which is a wooden trough shut close across at one extremity and open at the other. The sides consist of two boards at right angles to each other, from the meeting whereof a handle projects at right angles to their union. It is used by the labourer for conveying bricks and mortar to the bricklayer; for which purpose, when he has the latter office to perform, he strews dry sand on its inside, to prevent the mortar from sticking. 12. The *line pins*, which are of iron, for fastening and stretching the line at proper intervals of the wall, that each course may be kept straight in the face and level on the bed. The pins have a line attached to them of 60 ft. to each pin. 13. The *rammer*, used for trying the ground, as well as for beating it solid to the utmost degree of compression. 13. The *iron crow* and *pick axe*, for breaking and cutting through walls or moving heavy weights. 14. The *grinding stone*, for sharpening axes, hammers, and other tools. The following ten articles relate entirely to the preparation and cutting of guaged arches. 15. The *banker*, which is a bench from 6 to 12 ft. long, according to the number of workmen who are to work at it. It is 2 ft. 6 in. to 3 ft. wide, and about 2 ft. 8 in. high. Its use is for preparing the bricks for rubbed arches, and for other guaged work. 16. The *camber slip*, a piece of wood usually about half an inch thick, with at least one curved edge, rising about 1 inch in 6 feet, for drawing the sofite line of straight arches. When the other edge is curved, it rises about half that of the other, that is, about half an inch in 6 feet, for the purpose of drawing the upper line of the arch, so as to prevent it becoming hollow by the settling of the arch. The upper edge is not always cambered, many preferring it straight. The slip being sufficiently long, it answers the width of many openings; and when the bricklayer has drawn his arch, he delivers it to the carpenter to prepare the centre for it. 17. The *rubbing stone*. This is of a cylindrical form, about 20 inches diameter, but may be less. It is fixed at one end of the banker, upon a bed of mortar. After the bricks for the guaged work have been rough-shaped by the axe, they are rubbed smooth on the rubbing stone. The headers and stretchers, in return, which are not axed, are called *rubbed returns* and rubbed headers and stretchers. 18. The *bedding stone*, which is a straight piece of marble 18 or 20 inches in length, of any thickness, and about 8 or 10 inches wide. It is used to try the rubbed side of a brick, which must be first squared to prove whether its surface be straight, so as to fit it upon the leading *skew back*, or leading end of the arch. 19. The *square*, for trying the bedding of the bricks, and squaring the sofites across the breadth of the bricks. 20. The *bevel*, for drawing the sofite line on the face of the bricks. 21. The *mould*, for forming the face and back of the brick, in order to reduce it in thickness to its proper taper, one edge of the mould being brought close to the bed of the brick when squared. The mould has a notch for every course of the arch. 22. The *scribe*, a spike or large nail, ground to a sharp point, to mark the bricks on the face and back by the tapering edges of the mould, for the purpose of cutting them. 23. The *tin saw* used for cutting the sofite lines about one eighth of an inch deep, first by the edge of the level on the face of the brick, then by the edge of the square on the bed of the brick, in order to enter the brick axe, and to keep the brick from spalting. The saw is also used for cutting the sofite through its breadth in the direction of the tapering lines, drawn upon the face and back edge of the brick; but the cutting is always made deeper on the face and back of the brick than in the middle of its thickness, for the above-mentioned purpose of entering the axe. The saw is also used for cutting the false joints of headers and stretchers. 24. The *brick axe*, for axing off the sofites of bricks to the saw cuttings, and the sides to the lines drawn by the scribes. The bricks being always rubbed smooth after axing, the more truly they are axed the less labour will be requisite in rubbing them. 25. The *templet*. This is used for taking the length of the stretcher and width of the header. 26. The *chopping block*, for reducing the bricks to their intended size and form by axing them. It is made of any piece of wood that comes to hand, from 6 to 8 inches square, and generally supported upon two 14-inch brick piers, if only two men work at it; but if four men, the chopping-block must be lengthened and supported by three piers, and so on according to the number employed at it. It is about 2 ft. 3 in. in height. 27. The *float-stone*, which is used for rubbing curved work to a smooth surface, such as the cylindrical backs and spherical heads of niches, to take out the axe marks. It is, before application to them, made of a form reversed to the surface whereon it is applied, so as to coincide with it as nearly as possible in finishing.

1891. Before adverting to the *bond*, as it is technically called, of brick walling, which is the form of connection of the bricks with each other, we will stop to observe, that in working walls, not more than 4 or 5 feet should be brought up at a time; for as, in setting, the mortar shrinks and a general subsidence takes place, the part first brought up, if too large in quantity, will have come to its bearing before the adjacent parts are brought up, and thus fissures in the work and unequal settlements will take place. In carrying up any particular part above another, it should always be regularly sloped back to receive the adjoining parts to the right and to the left. On no account should any part of a wall be carried higher than one scaffold, except for some very urgent object.

1892. Previous to the reign of William and Mary, all the brick buildings in this island were constructed in what is called *English bond;* and subsequent to the reign in question, when, in building as in many other cases, Dutch fashions were introduced, we regret to say, much to the injury of our houses' strength, the workmen have become so infatuated with what is called *Flemish bond*, that it is difficult to drive them out of it. To the introduction of the latter has been attributed (in many cases with justice) the splitting of walls into two thicknesses; to prevent which, expedients have been adopted, which would be altogether unnecessary if a return to the general use of English bond could be established.

1893. In chap. i. sect x. of this book (1550. *et seq.*) we have spoken generally on walls; our observations here, therefore, in respect of them, will be confined to brick walls and their bond.

1894. *English bond* is that disposition of bricks in a wall in which (except at the quoins) the *courses* are alternately composed of *headers* and *stretchers*. In brick walling, and indeed in stone walling also, a *course* means the horizontal layer of bricks or stones whereof the wall is composed, being contained between two faces parallel to the horizon, and terminated on each side by the vertical face of the wall. The mass also formed by brick or stones in an arch are also termed courses, but receive the name of concentric courses. The term header is applied to a brick or stone whose small head or end is seen in the external face of the wall; and that of stretcher, to a brick or stone whose length is parallel to the face of the wall. We are therefore to understand by English bond, a continuation either of header or stretcher, continued throughout in the same course or horizontal layer, and hence we have described it as consisting of alternate layers of headers and stretchers (*fig.* 616.), the former serving to bind the wall together in a transverse direction or widthwise, and thus prevent its splitting, whilst the latter binds it lengthwise, or in a longitudinal direction. None but the English bond prevents the former occurrence, as work executed in this way, when so undermined as to cause a fracture, separates, but rarely breaks through the solid brick, as if the wall were composed of one entire piece.

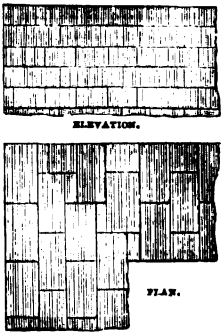


Fig. 616.

1895. The ancient Roman brickwork was executed on this principle; and its extraordinary durability is as much to be attributed to that sort of work being used for bonding it together, as to its extraordinary thickness.

1896. In this, as well as Flemish bond, to which we shall presently come, it will be observed, that the length of a brick being but 9 inches, and its width 4½ inches, in order to *break* the joints (that is, that one joint may not come over another), it becomes necessary near the angles to interpose a quarter brick or *bat*, *a*, called a *queen closer*, in order to preserve the continuity of the bond in the heading course. The bond, however, may equally be preserved by a three-quarter bat at the angle in the stretching course, in which case this last bat is called a *king closer*. In each case an horizontal lap of two inches and a half is left for the next header. The figure above given is that of a two-brick or 18-inch wall, but the student will have no difficulty in drawing, on due consideration of it, a diagram of the bond for any other thickness of wall; recollecting, first, that each course is formed either of headers or stretchers. Secondly, that every brick in the same course and on the same face of the wall must be laid in the same direction, and that in no instance is a brick to be placed with its whole length against the side of another, but in such way that the end of one may reach to the middle of the others that lie contiguous to it, excepting in the outside of the stretching course, where three-quarter bricks, or king closers, will of course be necessary at the ends, to prevent a continued upright joint in the face of the work. Thirdly, that a wall crossing at right angles with another will have all the bricks of the same level course in the same parallel direction, whereby the angles will be completely bonded. We shall close these observations with a recommendation to the young architect, founded on our own experience, on no account, in any building where soundness of work is a desideratum, to permit any other than English bond to be executed under his superintendence.

1897. *Flemish bond* is that wherein the same course consists alternately of headers and stretchers, which, in appearance, some may fancy superior to that just described. Such is not our opinion. We think that the semblance of strength has much to do with that of beauty in architecture. But there is in the sufferance of Flemish bond a vice by which strength is altogether lost sight of, which we shall now describe. It was formerly, though now partially, the practice to face the front walls of houses with guaged or rubbed bricks, or with at least a superior species of brick, as the malm stock; in the former cases, the bricks being reduced in thickness, and laid with a flat thin joint frequently, what the workmen call a *putty joint*, for the external face, the outer and inner work of the same courses in the same wall, not corresponding in height, could not be bonded together except where occasionally the courses fell even, where a header was introduced from the outside to tie or bond the front to the internal work. Hence, as the work would not admit of this, except occasionally, from the want of correspondence between the interior and exterior courses, the headers would be introduced only where such correspondence took place, which would only occur in a height of several courses. Thus a wall two bricks in thickness, if faced on both sides, was very little indeed better than three thin walls, the two outer half a brick thick, and the middle one a brick or 9 inches thick. Bricklayers having little regard for their character will, if not prevented by the architect, not only practise this expedient, but will also, unless vigilantly watched, when a better sort of brick is used for the facing, cut the headers in half to effect a paltry saving of the better material. In walls of one brick and a half in thickness, the strength of the wall is not diminished by the use of Flemish bond so much as in those of greater thickness, as may be seen by the diagram (*fig.* 617.). Many expedients have been invented to obviate the inconveniences of Flemish bond; but we think it rather useful to omit them, lest we should be considered as parties to a toleration of its use, for the continuation whereof no substantial reason can be assigned. As we have before observed, all that can be alleged in its favour is a fancy in respect of its appearance: but were the English mode executed with the same attention and neatness bestowed on the Flemish method, we should say it was equally beautiful; and therefore we shall thus close our notice of it.

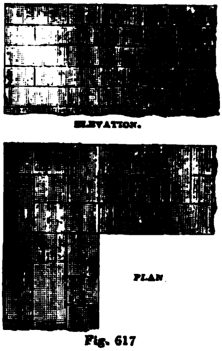


Fig. 617

1898. The two principal matters to be considered in brick walling are, first, that the wall be as strong as possible in the direction of its length. Secondly, that it be so connected in its transverse direction that it should not be capable of separating in thicknesses. To produce the first, independent of the extraneous aid of bond timbers, plates, &c., it is clear that the method which affords the greatest quantity of longitudinal bond is to be preferred, as in the transverse direction is that which gives the greatest quantity of bond in direction of the thickness. We will, to exemplify this, take a piece of walling 4 bricks long, 4 bricks high, and 2 bricks thick, of English bond: in this will occur 32 stretchers, 24 headers, and 16 half headers to break the joint, or prevent one joint falling over another. Now, in an equal piece of walling constructed in Flemish bond, there will occur only 20 stretchers and 42 headers; from which the great superiority of English bond may be at once inferred.

1899. Bond timber should be used in pieces as long as circumstances will admit. Some prefer its being laid in the centre of the wall, in which case, when dressings of wood are required on the interior face, wooden plugs must be provided to nail them to, which are not wanted where the bond timber is laid flush with the inner face of the wall.

1900. It will scarcely be necessary to inculcate the propriety of the mortar beds being as thin as possible. In good sound work they ought not to rise more that 11¾ inches. The mortar or cement should be such as will quickly set, to prevent the superincumbent weight pressing the joints closer, and thereby causing settlements which, even with the greatest care, often take place unequally. As often as it is conjectured, from the nature of the soil, or from the foundation being partly new and partly old, that the work will not come to its bearing equally, it is better to carry up the suspected parts separately, and to leave at their ends what are called *toothings*, by which junctions may be made when the weaker parts have come to their regular sound bearing. The thickness of walls has furnished the subject of previous pages; we shall therefore only add, that too much care cannot be bestowed on strengthening all angles as much as possible, and well connecting the return of one wall into another; that piers or pilasters are exceedingly useful in strengthening walls, inasmuch as they act by increasing the base whereon the whole stands; and, lastly, that in carrying up walls to any considerable height, it is usual to diminish their thickness by *sets off* as they rise. In houses, above the ground-floor, the sets off are usually made on the inside, having the outside in one face; but, if it be possible, it is better to set off equally from both faces, because of the better balance afforded.

1901. A bricklayer, with the assistance of one labourer, will in one day lay about 1000 bricks in common walling; hence he would complete a rod of brickwork in four days and a half, its area being 272¼ ft. superficial of the thickness of one brick and a half. When, however, there are many apertures or other interruptions to his work, he will be proportionably longer time over it. The weight of a rod of brickwork is about thirteen tons. Generally it may be taken as consisting of 4500 stock bricks, allowing for waste, 27 bushels of chalk lime, and 3 single loads of drift sand, or 18 bushels of stone lime and 3½ single loads of sand. In cement, of 36 bushels, and the same quantity of sharp sand.

1902. *Bricknogging* is a method of constructing a wall with a row of posts or quarters 3 feet apart, whose intervals are filled up with brickwork. It is rarely more than the width of a brick in thickness, and the bricks and timbers on the faces are flush. It should never be used where thickness can be obtained for a nine-inch wall.

1903. *Groined arches.* A groin is the angular curve formed by the intersection of two semi-cylinders or arches. When groins are formed of cones they are called conic groins; but our business here is with the more simple groins that occur in using brick arches. The centering for raising them belongs to the section Carpentry, to which the reader must refer. The turning a simple arch on a centre only requires care to keep the courses as close as possible, and to avoid the use of much mortar on the inner part of the joints. In executing a brick groin, the difficulty arises from the peculiar mode of making proper bond at the intersection of the two circles as they gradually rise to the crown, where they form an exact point. In the meeting or intersecting of these angles, the inner rib should be perfectly straight and perpendicular to a diagonal line drawn on the plan. After the centres are set, the application of the brick to the angle will immediately show in what direction it is to be cut. With respect to the sides, they are turned as for common cylindric vaults. The late Mr. George Tappen, an architect of great practical skill, introduced a method of constructing groins rising from octangular piers. which had the advantage of not only imparting strength to the angle, which in the common groin is extremely deficient, but of increasing the space for the stowage or removal of goods, and further, of strengthening the angles of the groin in this construction by carrying the band round the diagonals (*fig.* 618.) of equal breadth, and thus affording better bond to the bricks.

1904. Many ornamental brick cornices may be formed by but little cutting, and changing the position of the bricks employed, and several, indeed, without cutting, by chamfering only.

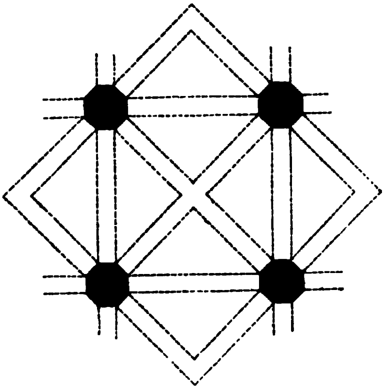


Fig. 618.

1905. *Niches* may be formed in brickwork. They constitute the most difficult part of the bricklayer's practice. The centre will be described under the section Carpentry. The difficulty in forming them arises from the thinness to which the bricks must be reduced at the inner circle, as they cannot extend beyond the thickness of one brick at the crown or top, it being the usual as well as much the neatest method to make all the courses standing.

1906. *Tiling* is the operation of laying the tiles on a roof for the covering of the building, and is effected with either plane tiles or pantiles, the former whereof is the most secure. Plane tiles are laid at different guages; when laid at a six-inch guage, 800 will cover a square; at a seven-inch guage, about 690. A plane tile weighs from 2 lbs. to 2½ lbs.

1907. Pantiling is laid to a ten-inch guage; and 180 pantiles, weighing from 5 lbs. to 5¼ lbs. each, will cover a square. From the frequent repairs necessary to tiled roofs, slating has become the most useful covering, and is generally employed, except for the most common buildings.

1908. The tiler's tools are—the *lathing hammer*, with two guage marks on it, one at 7 inches, the other at 7½ inches. The *lathing staff*, of iron, in the form of a cross, to stay the cross laths and clinch the nails. The *tiling trowel*, to take up the mortar and lay it on the tiles: it differs from the brick trowel, in being longer and narrower. The *bosse*, made of wood, with an iron hook, to hang on the laths or on a ladder, for holding the mortar and tiles. The *striker*, a piece of lath about 10 inches long, for separating and taking away the superfluous mortar at the feet of the tiles. The *broom*, to sweep the tiling after it is struck.

Sect. III.

MASONRY.

1909. Masonry is the science of preparing and combining stones so as to tooth, indent, or lie on each other, and become masses of walling and arching for the purposes of building. The tools of the mason vary as the quality of the stone upon which they are to act. About the metropolis the value of stone is considerable; and it is accordingly cut into slips and scantlings by a saw moved horizontally backwards and forwards by a labourer. In those parts where stone is abundant, it is divided into smaller scantlings by means of wedges. The principal tools of the mason are the *mallet* and *chisels*, the latter being formed of iron, except at the steel end, and the cutting edge being the vertical angle. The end of the chisel struck by the mallet is a small portion of a spherical surface, and projects on all sides beyond the adjoining part or hand hold, which increases in magnitude towards the middle of the tool, to the entering or cutting edge. The other tools of the mason are a level, a plumb-rule, a square, a bevel, straight and circular rules of divers sorts, for trying surfaces in the progressive states of the work.

1910. In London, the tools used to work the face of a stone are, successively, the *point*, the *inch tool*, the *boaster* (the operation of working with which is called *boasting*, as that with the point is called *pointing*), and the *broad tool*. The use of the point leaves the stone in narrow furrows, with rough ridges between them, which are cut away by the inch tool, and the whole made smooth by the boaster. The point is from ¼ to ⅜ of an inch broad, the boaster is 2 inches wide, and the broad tool 3½ inches at the cutting edge, which in use is always kept perpendicular to the same side of the stone. It performs two sorts of operations. Thus, imagine the impression made by the whole breadth of the tool at the cutting edge to be called a cavity; in one operation, the successive cavities follow one another in the same straight line, until the breadth or length of the stone is exhausted; successive equidistant parallel lines are then repeated in the same manner, until the tool has passed over the whole surface. This operation produces a sort of fluted surface, and is called *stroking*. In the other operation, each successive cavity is repeated in new equidistant lines throughout the length or breadth of the stone; then a new series of cavities is repeated throughout the length and breadth of the stone; and thus until its whole length or breadth is gone through. This operation is called *tooling*. The tools for working the cylindrical and conical parts of mouldings are of all sizes, from ⅛ of an inch upwards. Those for working convex mouldings are not less than half an inch broad, except the space be too confined to admit of such breadth.

1911. A stone is taken out of winding principally with points, and finished with the inch tool. In London, the squared stone used for facing buildings is usually stroked, tooled, or rubbed.

1912. In those parts of the country where the stone saved by the operation of sawing is not enough to compensate for the labour, the operation is altogether performed with the mallet and chisel.

1913. When stones, previous to the operation of hewing, are very unshapely, a *stone axe, jedding axe, scabbling-hammer*, or *cavil*, is used to bring the stone nearly to a shape; one end of the jedding axe is flat, and is used for knocking off the most protuberant angular parts, when less than right angles; the other end is pointed for reducing the different surfaces to nearly the intended form.

1914. In Scotland, besides the above described sorts of work, there are some other kinds termed *droved, broached*, and *striped*. Droving is the same as that called random tooling in England, or boasting in London. The chisel for broaching is called a *punch*, and is the same as that called a point in England. Broached work is first droved and then broached, as the work cannot at once be regularly done with the punch. Striped work must also be first droved and then striped. If broaching is performed without droving, which is sometimes done, it is never so regular, and the surface is full of inequalities. Of the three kinds of surfaces obtained, the droved is the cheapest.

1915. It is however to be observed, that the workman will not take the same pains to drove the face of a stone which is to be afterwards broached, as in that of which the droving is to remain the final finish. When the surface of stone is required to be perfectly smooth, it is accomplished by rubbing with sand or gritstone, and it is called rubbed work. In Aberdeen, where the stone is very hard, being a granite, they use the scabbling hammer, by which they pick the stone until the surface has nearly acquired the requisite form. This sort of work is called *nidged-work*, and the operation *nidging*.

WALLING.

1916. In stone walling the bedding joints are usually horizontal, and this should always, indeed, be so when the top of the wall is terminated horizontally. In building bridges, and in the masonry of fence walls upon inclined surfaces, the bedding joints may follow the general direction of the work.

The footings of stone walls should be constructed with stones as large as may be, squared and of equal thicknesses in the same course, and care should be had to place the broadest bed downwards. The vertical joints of an upper course are never to be allowed to fall over those below, that is, they must be made as it is called to *break joint*. If the walls of the superstructure be thin, the stones composing the foundations may be disposed so that their length may reach across each course from one side of the wall to the other. When the walls are thick, and there is difficulty in procuring stones long enough to reach across the foundations, every second stone in the course may be a whole stone in breadth, and each interval may consist of two stones of equal breadth, that is, placing header and stretcher alternately. If those stones cannot conveniently be had, from one side of the wall lay a header and stretcher alternately, and from the other side another series of stones in the same manner, so that the length of each header may be two thirds, and the breadth of each stretcher one third of the breadth of the wall, and so that the back of each header may come in contact with the back of an opposite stretcher, and the side of that header may come in contact with the side of the header adjoining the said stretcher. In foundations of some breadth, for which stones cannot be procured of a length equal to two thirds the breadth of the foundation, the works should be built so that the upright joints of any course may fall on the middle of the length of the stones in the course below, and so that the back of each stone in any course may fall on the solid of a stone or stones in the lower course.

1917. The foundation should consist of several courses, each decreasing in breadth as they rise by sets off on each side of 3 or 4 inches in ordinary cases. The number of courses is necessarily regulated by the weight of the wall and by the size of the stones whereof these foundations or footings are composed.

A wall which consists of unhewn stone is called a rubble wall, whether or not mortar is used. This species of work is of two kinds, coursed and uncoursed. In the former, the stones are guaged and dressed by the hammer, and thrown into different heaps, each containing stones of the same thickness. The masonry is then laid in horizontal courses, but not always confined to the same thickness. The uncoursed rubble wall is formed by laying the stones in the wall as they come to hand, without guaging or sorting, being prepared only by knocking off the sharp angles with the thick end of the scabbling hammer.

1918. Walls are most commonly built with an ashlar facing, and backed with brick or rubble work. In London, where stone is dear, the backing is generally of brickwork; which does not occur in the north and other parts, where stone is cheap and common. Walls faced with ashlar and backed with brick or uncoursed rubble are liable to become convex on the outside from the greater number of joints, and, consequently, from the greater quantity of mortar placed in each joint, as the shrinking of the mortar will be in proportion to the quantity; and therefore such a wall is inferior to one wherein the facing and backing are of the same kind, and built with equal care, even supposing both sides to be of uncoursed rubble, than which there is no worse description of walling. Where a wall consists of an ashlar facing outside, and the inside is coursed rubble, the courses at the back should be as high as possible, and the beds should contain very little mortar. In Scotland, where there is abundance of stone, and where the ashlar faces are exceedingly well executed, they generally back with uncoursed rubble; in the north of England, where they are not quite so particular with their ashlar facings, they are much more particular in coursing the backings. Course rubble and brick backings admit of an easy introduction of bond timber. In good masonry, however, wooden bonds should not be continued in length; and they often weaken the masonry when used in great quantity, making the wall liable to bend where they are inserted. Indeed, it is better to introduce only such small pieces, and with the fibres of the wood perpendicular to the face of the wall, as are required for the fastenings of battens and dressings.

1919. In ashlar facing, the stones usually rise from 28 to 30 inches in length, 12 inches in height, and 8 or 9 inches in thickness. Although the upper and lower beds of an ashlar, as well as the vertical joints, should be at right angles to the face of the stone, and the face, bed, and vertical joints at right angles to the beds in an ashlar facing; yet, when the stones run nearly of the same thickness, it is of some advantage, in respect of bond, that the back of the stone be inclined to the face, and that all the backs thus inclined should run in the same direction; because a small degree of lap is thus obtained in the setting of the next course, whereas, if the backs are parallel to the front, no lap can take place when the stones run of an equal depth in the thickness of the wall. It is, moreover, advantageous to select the stones so that a thicker one and a thinner one may follow each other alternately. The disposition of the stones in the next superior course should follow the same order as in the inferior course, and every vertical joint should fall as nearly as possible in the middle of the stone below.

1920. In every course of ashlar facing in which the backing is brick or rubble, *bond*, or, as they are called in the country, *through* stones should be introduced, their number being proportioned to the length of the course; every one of which stones, if a superior course, should fall in the middle between every two like stones in the course below. And this disposition should be strictly attended to in all long courses. Some masons, in carrying up their work, to show that they have introduced a sufficient number of bond stones into their work, choose their bond stones of greater length than the thickness of the wall, and knock or cut off their ends afterwards. But this is a bad practice, as the wall is liable to be shaken by the force used in reducing, by chiselling or otherwise cutting away the projecting part, and sometimes with the chance even of splitting the bond stone itself.

1921. In piers, where the jambs are coursed with ashlar in front, every alternate jamb stone should go through the wall, with its beds perfectly level. If the jamb stones are of one entire height, as is often the case when architraves are wrought upon them, and also upon the lintel crowning them, of the stones at the ends of the courses of the pier which are to adjoin the architrave jamb, every alternate stone should be a bond stone; and if the piers be very narrow between the apertures, no other bond stones will be necessary in such short courses. When the piers are wide, the number of bond stones is to be proportioned to the space. Bond stones, too, must be particularly attended to in long courses above and below windows. They should have their sides parallel, and of course perpendicular to each other, and their horizontal dimension in the face of the work should never be less than the vertical one. The vertical joints, after receding about three quarters of an inch from the face of the work with a close joint, should widen gradually to the back, so as to form hollow wedge-like figures for the reception of mortar and *packing*. The adjoining stones should have their beds and vertical joints filled with oil-putty, from the face to about three-quarters of an inch inwards, and the remaining part of the beds with well-prepared mortar. Putty cement is very durable, and will remain prominent when many stones are in a state of dilapidation, through the action of the atmosphere upon them. The use of the oil-putty is at first disagreeable, from the oil spreading over the surface of the contiguous stones; but after a time this unpleasant look disappears, and the work seems as though of one piece.

1922. All the stones of an ashlar facing ought to be laid on their natural beds. From inattention to this circumstance, the stones often flush at the joints; and, indeed, such a position of the lamina much sooner admits the destructive action of the air to take place.

1923. Where walls or insulated pillars of very small dimensions are to be carried up, every stone should be carefully bedded level, and be without concavity in the middle. If the beds should be concave, as soon as the superimposed weight comes to be borne by the pier or pillar, the joints will in all probability begin to flush; and it is moreover better, if it be possible, to make every course in the masonry of such a pier or pillar in one stone.

1924. When large columns are obtained in a single block, their effect, from that circumstance alone, is very striking; but as this is not very often to be accomplished, the next point is to have as few and as small joints as possible; and the different stones, moreover, ought to be selected with the view, as much as possible, of concealing the joints, by having the blocks as much of the same colours as possible. It will immediately, of course, occur to the reader, that vertical joints in columns are inadmissible.

COLUMNS.

1925. The stones for an intended column being procured, and the order in which they are to be placed upon one another having been determined, we must correctly ascertain the exact diameter for the two ends of each of them. To effect this, draw an elevation of the column proposed to its full size, divide it by lines parallel to the base into as many heights as the column is intended to contain stones, taking care that none of the heights exceed the lengths the stones will produce; the working of the stones to the diameters thus obtained then becomes easy. The ends of each stone must first be wrought so as to form exactly true and parallel planes. The two beds of a stone being thus formed, find their centres, and describe a circle on each of them; divide these circles into the same number of equal parts, which may, for example, amount to six or eight; draw lines across each end of the stone, so that they will pass through the centre and through the opposite divisions of the same end. The extremities of these lines are to regulate the progress of the chisel along the surface of the stone; and therefore, when those of one end have been drawn, those of the other must be made in the same plane, or opposite to them respectively. The cylindrical part of the stones must be wrought with the assistance of a straight edge; but for the swell of a column, a diminishing rule, that is, one made concave to the line of the column, must be employed. This diminishing rule will also serve to plumb the stones in setting them. If it be made the whole length of the column, the heights into which the elevation of the column is divided should be marked upon it, so that it may be applied to give each stone its proper curvature. But as the use of a very long diminishing rule is inconvenient when the stones are in many and short lengths, rules or rods may be employed corresponding in length to the different heights.

STAIRS.

1926. Nothing to perplex will occur in carrying up stairs which are supported by a wall at both ends, because the inner ends of the steps may either terminate in a solid *newel*, or be tailed into a wall surrounding an open newel. Where elegance is not required, and where the newel does not exceed 2 feet 6 inches, the ends of the steps may be conveniently supported by a solid pillar; but when the newel is thicker, a thin wall surrounding the newel would be cheaper. In stairs to basement stories, where geometrical stairs are used above, the steps next to the newel are generally supported upon a dwarf wall.

1927. In *geometrical stairs*, the outer end of each step is fixed in the wall, and one of the edges of every step supported by the edge of the step below, and formed with *joggled* joints, so that no step can descend in the inclined direction of the plane nor in a vertical direction; the sally of every joint forms an exterior obtuse angle on the lower part of the upper step, called a back rebate, and that on the upper part of the lower step of course an interior one, and the joint formed of these sallies is called a *joggle*, which may be level from the face of the risers to about one inch within the joint. Thus the plane of the tread of each step is continued one inch within the surface of each riser; the lower part of the joint is a narrow surface, perpendicular to the inclined direction or soffit of the stair at the end next to the newel.

1928. With most sorts of stone the thickness of every step at the thinnest place need not exceed 2 inches for steps of 4 feet in length; that is, measuring from the interior angle of every step perpendicular to the rake. The thickness of steps at the interior angle should be proportioned to their length; but allowing that the thickness of the steps at each of the interior angles is sufficient at 2 inches, then will the thickness of them at the interior angles be half the number of inches that the length of the steps is in feet; for instance, a step 5 feet long would be 2½ inches at that place.

1929. The stone platforms of geometrical stairs, that is, the *landings*, *half paces*, and *quarter paces*, are constructed of one or more stones, as they can be procured of sufficient size. When the platform consists of two or more stones, the first of them is laid on the last step that is set, and one end tailed in and wedged into the wall; the next stone is joggled or rebated into the one just set, and the end also fixed into the wall, as that and the preceding steps also are; and every stone in succession, till the platform is completed. When another flight of steps is required, the last or uppermost platform becomes the spring stone for the first step of it, whose joint is to be joggled, as well as that of each succeeding step, similarly to those of the first flight. The principle upon which stone geometrical stairs are constructed is, that every body must be supported by three points placed out of a straight line; and therefore, that if two edges of a body in different directions be secured to another body, the two bodies will be immoveable in respect to each other. This last case occurs in the geometrical staircase, one end of each stair stone being tailed into the wall so as to be incapable of tilting, and another edge resting either on the ground itself, or on the edge of the preceding stair stone or platform, as the case may be. The stones which form a platform are generally of the same thickness as those forming the steps.

ON THE SCIENTIFIC OPERATIONS OF STONE CUTTING.

1930. The operations by which the forms of stones are determined, so as to combine them properly in the various parts of an edifice, are founded on strictly geometrical principles, and require the greatest care and exactness in execution. It is only by a thorough knowledge of the nature of these operations that the master mason is able to cut and carve the parts which, when joined together, compose the graceful arch, the light tracery of the Gothic vault, or the graceful and magnificent dome. The method of simple walling, and its general principles, have been given in this book, chap. i. sect. x. In what follows we propose to confine ourselves, 1st, to the leading operations necessary to *set out* the simple arch or vault, and the groins formed by it; 2d, to the forms produced by vaults with plain and curved surfaces intersecting; 3d, and lastly, to dome vaulting; giving such examples as will so initiate the student that he may, we trust, have little, if any, difficulty in resolving any case that may occur, and reminding him that if he well understand the section already submitted to him on Descriptive Geometry, his labour will be much abridged, not only in what immediately follows, but in that section which treats hereafter on Carpentry.

1931. I. Of the Construction of Arches and simple Vaults, and the Groins formed by their Intersection. In arches and simple vaults we have to ascertain the exact form of the arch in all its parts, and the direction of its joints; both which points are dependent on the geometrical properties of the curve used for the arch.

1932. *To find the joints of a flat arch without using the centre of the circle of which the arch is a part.* Divide the arch AB (*fig.* 619.) into as many equal parts as there are intended to be arch stones, at the points 1, 2, 3, &c. From A, with any convenient radius, describe an arc at *a*, and from 2, with the same radius, describe another arc, crossing the first at *a*, and join *a*1; then 1 is the first joint from A. To find the joint passing through 2; with the same radius as before, from the joints 1 and 3 as centres, describe arcs cutting each other at *b*, and draw 2*b*; then 2*b* is the second joint. In the same manner all the other joints between A and B will be found. To find the *skew backs*, or abutting joints AC and DB; with a radius equal to 1*a*, from the centre A describe an arc at C; from the centre 1, with the radius A*a*, describe an arc cutting the former at C, and draw the line AC, which will be the springing bed of the arch. In the same manner the joint BD may be found.

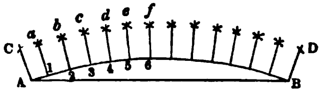


Fig. 619.

1933. The joints of any arch may be drawn with considerable accuracy by setting off at equal distances a point in the curve on each side of the place for the joint, and from these points, as centres, with any radius, arcs to intersect, through whose intersections lines being drawn, will give the directions of the joints.

1934. *To draw an elliptical arch to any two dimensions by circular arcs.* Draw the straight line AB (*fig.* 620.). Bisect AB in C by the perpendicular D*g*, make CA and CB each equal to half the span of the arch, and make CD equal to the height, and A*j* parallel and equal to CD. In C*g* make C*k* equal to CD. Divide A*j* and AC each into two equal parts. Through 1 in AC draw *kn*, and through 1 in A*j* draw 1D, cutting *kn* at *n*. Bisect *n*D by the perpendicular *lg*, and from *g* with the radius *gn* or *g*D describe the arc *n*D*ih*. Draw *gh* parallel to AB, and join *h*B, and produce *h*B to meet the arc *n*D*h* in *i*. Join *gi* cutting AB in *f* and make C*e* equal to C*f*. Join *ge*, and produce it to meet the arc *n*D*h* in *n*. From *f* with the radius *fi* describe the arc *i*B, and from *e* with the radius *e*A describe the arc A*mn*. Then A*m*D*i*B is the arch required.

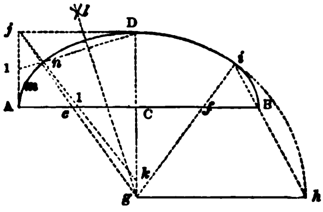


Fig. 620.

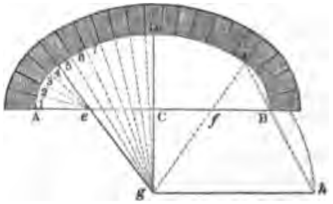


Fig. 621.

1935. *An elliptical arch* ADB (*fig.* 621.) *being given, to draw the joints for a given number* *of arch stones.* Find the centres *e*, *f*, *g* in the same manner as if the arch were to be drawn; join *ge* and produce it to meet the arch; also join *g*, *f* and produce it to meet the arc in *i*. Divide the elliptical curve ADB into as many equal parts as the number of arch stones. From the centre *e* draw lines through the points of division in the curve between A and where *ge* meets the curve, and from the centre *g* draw lines through all the intermediate points between *ge* and *gf*, and lastly draw lines from *f* through all the intermediate points between *i* and B, and the parts of the lines thus drawn on the outside of the curve will be the joints of the arch stones.

1936. In very large arches it will be desirable to find five centres, as in *fig.* 622., and these will be obtained by finding two intermediate points in each half of the curve instead of one; then bisecting each pair of adjacent points by a perpendicular, we shall have the centres *e*, *h*, *g*, *i*, *f*, to be used for drawing the joints in the same manner as in the preceding figure.

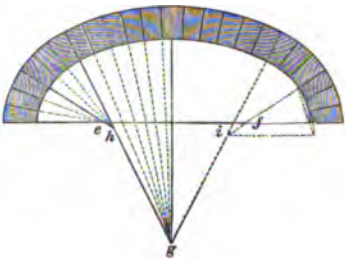


Fig. 622.

1937. The above methods are sufficient for ordinary purposes; but where strict accuracy is required, the following method is mathematically true. Suppose any joint, as *gk*, is required to be drawn (*fig.* 623.), and that the point D is the middle of the arch and the point C the middle of the springing line; then with the distance CA or CB, from the point D describe an arc at *e* and another at *f* to cut AB at *e* and *f*. Draw *eg* and *fg*; produce *eg* to *i* and *fg* to *h*, bisect *hgi* by the straight line *gk*, which will be the joint required. In the same manner, by drawing lines from *e* and *f* to each point of division, and bisecting the angle, lines for the other joints may be drawn.

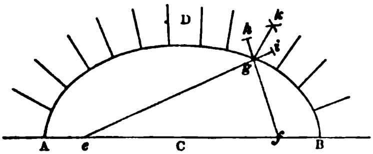


Fig. 623.

1938. *To draw a Gothic arch to any given dimensions* (*fig.* 624.). Draw the straight line

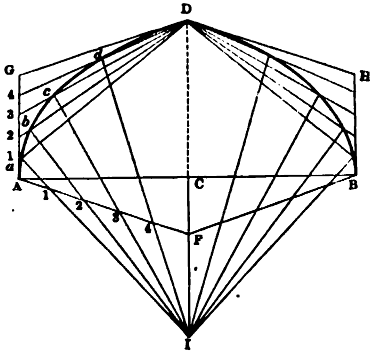


Fig. 624.

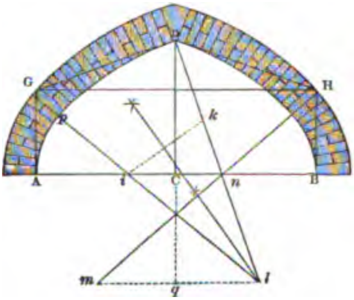


Fig. 625.

AB equal in length to the span of the arch. Bisect AB in C by the perpendicular DI. and draw AG and BH parallel to DI. Make CD equal to the height of the arch, and the angles CDG and CDH each equal to half the vertical angle; make CF equal to the difference between CD and AG and join FA and FB. Divide AG and AF each into the same number of equal parts, counting each from the point A. Through the points 1, 2, 3, 4 in AF draw I*a*, I*b*, Ic, I*d*, and through the points 1, 2, 3, 4 in AG draw 1D, 2D, 3D, 4D cutting I*a*, I*b*, Ic, I*d* at the points *a*, *b*, *c*, *d*, then through the points A*abcd*D draw a curve; which will be half of the Gothic arch required.

1939. *To draw the joints of the arch stones of a Gothic arch* (*fig.* 625.). Having formed the angles CDG and CDH as before, make A*i* equal to AG and draw D*l* perpendicular to DG. In D*l* make D*k* equal to A*i* and join *ik*. Bisect *ik* by a perpendicular meeting D*l* in *l*. Produce *li* to *p*. Divide the curve into as many equal parts as the arch stones are to be in number. Then *i* will be the centre of the joints which pass through all the points between A and p, and l will be the centre for drawing the joints of the arch stones which pass through all the points between p and D.

1940. The reason for the foregoing rule is obvious; for the joints are merely made to radiate to the centres of the arcs of circles whereof the arches themselves are formed; as in subsections 1934, 1935. they were drawn to the centres of the approximating circles wherefrom the elliptical curves were struck.

1941. *To describe a parabolic curve for a pointed or Gothic arch by means of a series of lines touching the curve, the dimensions of the arch and the angles it forms at the crown being given.* Draw the straight line AB (*fig.* 626.) and draw CD perpendicular to AB. Make CD equal to the height of the arch, CA and CB each equal to half the span. Make the angles CD*e* and CD*f* each equal to half the vertical angle. Divide A*e* and *e*D each into the same number of equal parts, and through the corresponding points of division draw lines which will form one half of the arch: the other half DB may be found in the same manner.

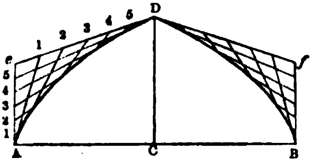


Fig. 626.

1942. *To draw the joints of the arch stones to the above sort of arch.* Draw the chords AD, DB for each half of the arch (*fig.* 627.); divide the arch into as many equal parts as there are to be arch stones. Let it now be required to draw a joint to any point *h*: bisect AD in *k*, and join *ek* cutting the curve in *l*. Draw *hg* parallel to A*k*, cutting *ek* in *g*, and in *el* make *li* equal to *lg*. Join *hi* and draw *hm* perpendicular to *hi*. Then *hm* is the joint required. In the same manner all the remaining joints will be found.

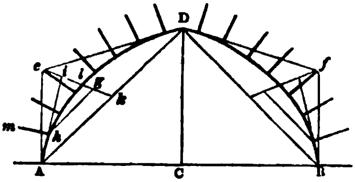


Fig. 627.

1943. *To describe a rampant pointed arch, whose span, perpendicular height, and the height of the ramp are given.* Draw the straight line AB (*fig.* 627.), and make AB equal to the span of the arch. Draw BC perpendicular to AB, and make BC equal to the height of the ramp. Bisect AC in D, and draw DE perpendicular to AB. Make DE equal to the height of the arch; draw A*f* and C*g* parallel to DE, and make A*f* and C*g* equal to about two thirds of DE. Join *f*E and E*g*. Divide A*f* and *f*E each into the same number of equal parts, and through each two corresponding points of division draw a straight line. All the lines thus drawn will give one half of the curve. The other half may be drawn in the same manner. To find the joints (*fig.* 629.) proceed as for a plain arch in the last example.

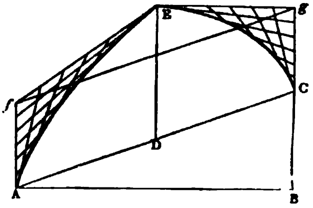


Fig. 628.

1944. II. Of the Construction of intersecting Vaults or Groins. The forms of vaults may be so adapted to one another that the lines of intersection shall be in planes, and these planes the diagonals of the plan of the intersecting part of the vaults; if, however, they be not so adapted, the lines of intersection will be curved on the plan, and these curves it is necessary to ascertain in making both the moulds and the centerings for executing the work.

1945. *To determine the form of a vault to intersect with a given one in the plane of the diagonal, and also to find the diagonal rib for the centering.* Let the given vault be EIF (*fig.* 630.) and AC and BD the diagonals, crossing in *f*. Draw *f*I perpendicular to EF, cutting EF in *c*. In the arc IF take any number of points *ab*, and draw *ag*, *bh* parallel to I*f*, cutting EF in *d*, *e*, and the diagonal AC in *g*, *h*. Draw *fp*, *gq*, *hr* parallel to EF, cutting the base GH at *m*, *n*, *o*. Make *mp*, *nq*, *or* each respectively equal to cI, *da*, *eb*. Draw *f*I′, *gk*, *hl*, perpendicular to AC, and make *f*I′, *gk*, *hl* respectively equal to cI, *da*, *eb*. Make

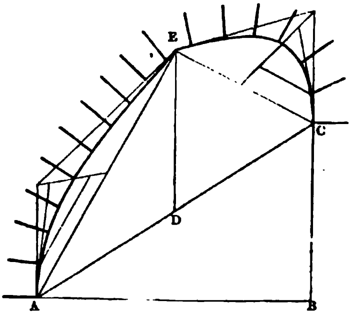


Fig. 629.

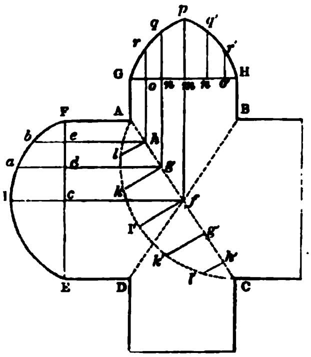


Fig. 630.

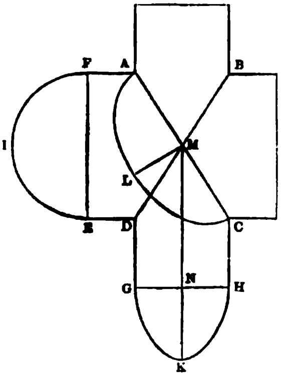


Fig. 631.

fg', *fh'* each respectively equal to *fg*, *fh*. Draw *g'k'*, *h'l'* parallel to *f*I'. Make *g'k'* equal to *gk*, *h'l'* equal to *hl*; also make *mn'*, *m'o'* each respectively equal to *mn*, *mo*. Draw the arcs *pqr*, *p'q'r*, as also I'*kl*, I'*k'l'*; then, through the points thus found, draw the curves upon their bases AC and GH, and that on GH is the form of the intersecting vaults, and that on AC is the form of the angle rib. If the form of the given arch be that of a semicircle EIF (*fig.* 631.), let ABCD be the angular points of the plan, AC and DB the diagonals, cutting each other at M. Draw MK parallel to GD, or CH cutting GH in N. Draw ML perpendicular to AC, and make ML equal to the radius of the semicircle. Then, with the transverse axis AC, and semi-conjugate axis ML, describe a semi-ellipse, which will be one of the angle ribs, as required. Also make NK equal to the said radius; then with the lesser axis and the semi-greater axis NK describe the semi-ellipse GKH, which is the form of the other vault.

1946. The same method applies in *fig.* 632., where the narrow opening is a semi-circle, and the wide one, consequently, a semi-ellipse, having its minor axis vertical and its major axis horizontal.

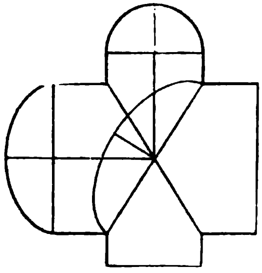


Fig. 632.

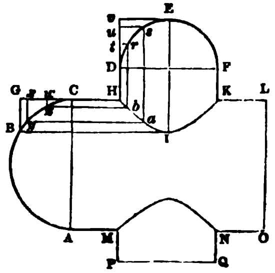


Fig. 633.

1947. *When two circular-arched vaults of different heights intersect, to determine the plan of the arrises in which the arches meet.* Let ABC (*fig.* 633.) be the arch of the main vault, and DEF that of the lesser vault; ACLO the plan of the main vault, and DPQF that of the lesser vault; and let the two vaults intersect each other at the points HKNM. Also, let E be the middle point of the lesser semi-circular arc DEF. Produce HD to *v*, and in the arch DE take any number of points *rs*, and draw *rb*, *sa*, EI parallel to DH. Draw *rt*, *su*, E*v* parallel to DF, cutting D*v* at the points *tuv*, and produce HC to G. In CG make C*w*, C*x*, CG respectively equal to D*t*, D*u*, D*v*, and draw *wz*, *xy*, GB parallel to AC, cutting the semi-circle ABC in the points *zy*B. From the points B*yz* draw BI, *ya*, *zb*, parallel to CL. Then through the points I*ab* draw a curve, which will be one half of the plan of the arris. The other half will be found in the same manner.

1948. The method of tracing the plan of the groins is the same (see *fig.* 634.) when the vaults intersect obliquely.

1949. *To find the plan of the intersections of two arches of the same height, and either of the same or different species.* Let the sections of the two arches be ABC and DEF (*fig.* 635.), the arcs AB, BC being equal to each other, and the arcs DE, EF equal to each other;

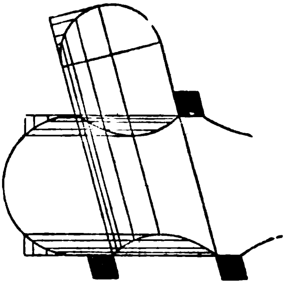


Fig. 634.

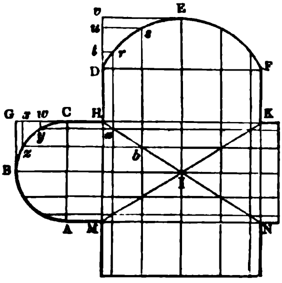


Fig. 635.

and let H, K, N, M be the points where the two arches intersect each other on the plan. Divide either of the arcs BC or DE into parts, equal or unequal; as, for example, in the arc DE take any number of points *r*, *s* at pleasure, and draw *ra*, *sb*, EI perpendicular to DF. Produce HD to *v*, and draw *rt*, *su*, E*v*, parallel to DF, cutting D*v* in *t*, *u*, *v*. Produce HC to G, and make C*w*, C*x* respectively equal to D*t*, D*u*; and as the arches are equal in height, CG will be equal to D*v*. Draw *wy*, *xz*, GB, parallel to AC, cutting the arc BC in the points *y*, *z*, and touching it in B. Draw *ya*, *zb* and BI parallel to HK, and through the points H*ab*I draw the curve H*ab*I, which will be half the plan of the groin as required. The other half IN and the other groin MK will be found in the same manner.

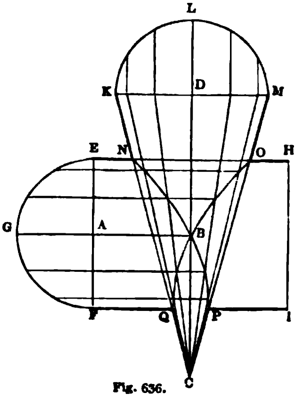


Fig. 636.

1950. *To find the plan of the groins produced by the intersection of a cylindric and a conic vault, the angle of position of the axis, the diameter of the cylinder, and the plan of the conic vault being given.* Let AB (*fig.* 636.) be the axis of the cylinder, CD that of the cone, C being the apex, and D the point through which the base passes. Through any point A in AB draw EF perpendicular to AB, and make AE and AF each equal to the radius of the cylinder, and draw EH and FI parallel to AB. Through D draw KM perpendicular to CD, and make DK and DM each equal to half the diameter of the cylinder. Join KC and MC, cutting EH and FI in the points N, O, P, Q. Divide the semicircles FGE and KLM into parts, whereof the corresponding ones are equal to one another. From the points of division in the semicircle EGF draw lines parallel to AB; and through the corresponding points in the semicircle KLM draw lines perpendicular to the diameter KM, cutting KM. From the points of section draw lines to the apex C of the cone, cutting the former drawn through the points in the semicircumference FGE. Through each set of corresponding points draw a curve, and the two curves will represent the arrisses of the groin on the plan. If in an octagonal ground vault the octagonal range be cylinders, and the cross vaults, which tend to the centre, diminish to a line of the height of the vault, the following construction applies:— Let EFGHI (*fig.* 637.) be the exterior side of the vault, which is both equilateral and equiangular, and let JKLMN be the line of the exterior surface of the inner wall; so that the lines EJ, FK, GL, HM, IN, which pass through every two corresponding angles, may tend to the centre O of the groin vault. Let the sections of the given ribs be PQR and STU, so that PR of the rib PQR may stand at right angles to the sides EF and JK and the side SU of the rib STU on the middle of the side FG. Divide the two bases PR and SU in the same proportion, and through the joints of division in SU draw lines from the centre O of the ground vault to meet the curve STU; and

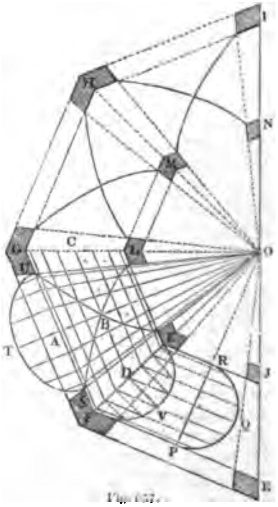


Fig. 637.

through the points of division in the base PR of the cross rib PQR draw lines parallel to EF, to terminate in the line FK, and in the semicircle PQR. From the points where these lines meet FK, draw perpendiculars on one side of FK, and make the heights of these perpendiculars respectively equal to the ordinates of the arc PQR; and through the ends of these perpendiculars draw a curve FVK, which will be the angle rib. From the points of meeting in the line FK draw lines parallel to FG, and through the points of division in SU draw lines to the centre O, intersecting the former lines drawn from the points of division in FK; through the corresponding points of intersection draw the curves SBL and KBU, which will form the plan of the angle.

1951. In single groins the centres are made for the widest avenue, and are covered over with boards (*fig.* 638.), so that the top of the boards may form the surface required for turning the arch upon the intersections; or the angles are found by the following practical method. The groins meet in the points I, C (*fig.* 639.), upon the boarding of the two groins. Place the straight edge of a board upon the point I, so as to range over the line GH on the plan. Then set up another straight edge upon the point H, so as to be vertical, and the straight vertical edge will meet the horizontal edge; then apply a third straight edge to each of the other two straight edges, so that it may also come in contact with the boarding. After this draw a line along this third straight edge upon the boarding as far as may be found convenient; shift the moveable or third straight edge, and apply it in the same manner to another adjoining portion of the surface of the boarding. Proceed in the same manner until the whole line be completed on the surface. By this means, the necessity of laying down lines for the covering is avoided. The lines being thus drawn, ribs for the cross vaults are fixed on the top of the boarding; so that, making proper allowance for the thickness of the same, its surface, when fixed, may form the true surface of the other cross vault. The ribs fixed upon the boarding to form the cross vaults are called *jack ribs*.

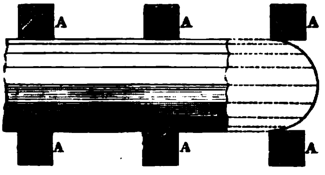


Fig. 638.

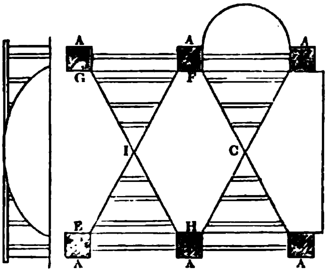


Fig. 639.

1952. The mode of constructing the curves by lines is shown for a rectangular groin in *fig.* 640., in which A is the plan, B the elevation. Here, to find the pliant moulds for forming the groins on the surface of the boarding, and working the arch-stones, describe a semicircle on one of its sides, and divide it into any convenient number of equal parts. Draw lines perpendicular to the base or diameter, the semicircle being supposed to be within the piers; the ordinates will cut the diagonals; but if it be laid down on the outside, the ordinates must be produced until they cut the diagonals. From the points where the ordinates cut the diagonals, draw lines parallel to the other side of the groin, and produce the side on which the diameter of the semicircle is placed, and extend the semicircular arc with its divisions upon any convenient part of the line thus produced. Through the points of division draw perpendiculars, so as to intersect with the former parallel lines; then through the points of intersection draw the curve, as shown at C, which will be the mould required.

1953. Sometimes several vaults meet in one common centre, as in *fig.* 641., which exhibits the plan of an equiangular and equilateral groined vault, constructed of semicircular arches.

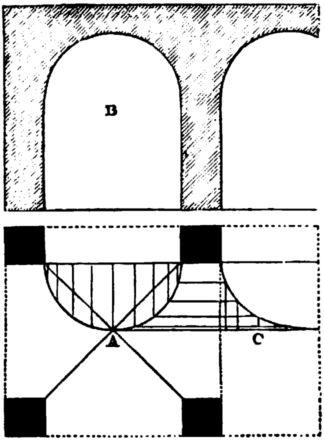


Fig. 640.

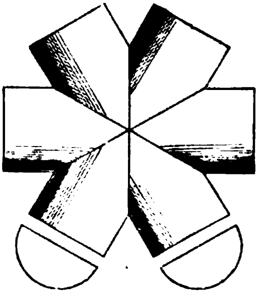


Fig. 641.

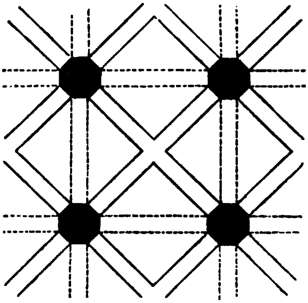


Fig. 642

1954. Where the piers supporting groins (*fig.* 642.) are made octangular, the angles of the groins should be cut off or arched as ribs, by which they are rendered much stronger than when they are square. In stone groins, where the arch is cut off, there is no advantage in point of strength, and rather a defect in point of appearance, to the groined angles.

1955. Arches intersecting a coved ceiling are similar to groins. Such arches are called *lunettes*, and are generally practised for semicircular-headed windows piercing the coves in the ceiling: *fig.* 643. exhibits a plan and section of such arches.

1956. A dome is a solid, which may be conceived to be generated by the figure of the base diminishing as it rises, till it becomes a point at the summit; and when a dome has a polygonal base, the arches are plain arches, and the construction is similar to that of a groin. A domed ceiling of this kind upon a rectangular plan is shown in plan B (*fig.* 644.); the sections AA being elliptical in the top, and with lunette windows. C shows the geometrical construction.

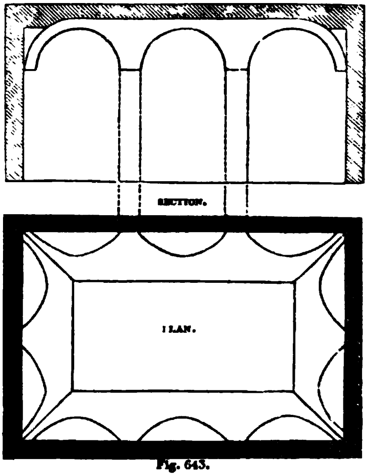


Fig. 643.

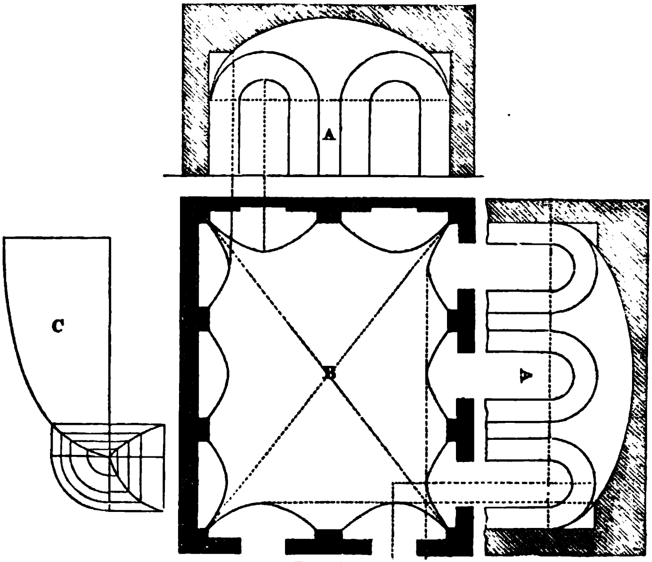


Fig. 644.

1957. When arches intersect an inclined vault, and the projections of the arrisses cross each other at right angles, and the angle of elevation of one of the semicircular vertical ribs of the ascending avenue or opening is given to obtain the geometrical construction; so that the cross arches may be cylindrical surfaces. Draw the straight line AB (*fig.* 645.) to represent the axis of the inclined vault, and draw CD perpendicular to AB. Produce D to *e* and *h*; make AC and AD each equal to the radius which forms the edges of the ribs; draw *h*N parallel to AB, and make the angle N*ho* equal to the inclination of the axis represented by its plan AB. In the line *ho* take any point *p*, and draw *qr* parallel and *ps* perpendicular to *h*N. Make *ps* equal to AC or AD, and through *s* draw L*t* parallel to *ho*. Draw *pu* perpendicular to L*t*, cutting it in *u*. Produce *pu* to *v*. Set the circumference of the inclined vault from *u* to *v*, divided into the equal parts *u*, 1, 1, 2; 2, 3; 3*v*, at the points 1, 2, 3. Divide each of the quadrants *qs*, *sr*, into the same number of equal parts at the points 1, 2, 3, and through these points and in *uv* draw 1*a*, 2*b*, 3*c* parallel to *vt*, and through the points 1, 2, 3, in the curve *qs*, draw *i*L, 1*a*, 2*b*, 3*c*, parallel to *pu*. Through all the points L, *a*, *b*, *c* draw the curve L*abcv*, and this will be the pliable mould for forming the angle or groin over the plan, and for working the arch stones. Draw D*k* parallel to A*z*. Let E divide the circumference CED into the two equal parts EC, ED; divide the arcs DE, EC into the same number of equal parts as *uv* at the points 1, 2, 3, and draw 1*w*, 2*x*, 3*y*, E*z*, parallel to AB; also through the points 1, 2, 3 in the quadrant *qu* draw *gk*, 1*w*, 2*x*, 3*y*, *uz*, perpendicular to *y*N; then through the points *k*, *w*, *x*, *y*, *z*, draw a curve, which will be the plan of the groin whereof the stretch-out is L*abcv*. In the same manner the other half of the plan will be found, as also the whole of the other parts.

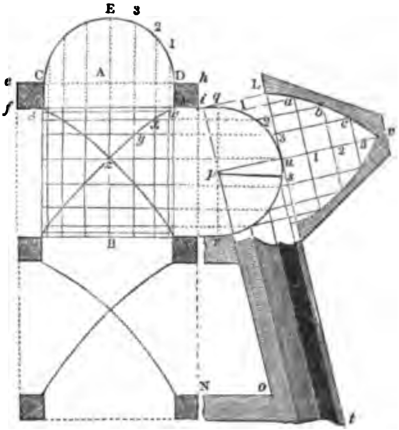


Fig. 645.

1958. *The form of an arch crossing an inclined groined vault at right angles, and the plan of the diagonal ribs being given; to find the arch of the level vault.* Let AB, BC (*fig.* 646.) be the plan of the axis of the vaults. Through any point A in AB draw DF perpendicular to AB, and make AD and AF each equal to the horizontal breadth of the vault. Draw DG and FH parallel to AB; draw also any line LK parallel to AB, cutting BC in C, and make the angle KIL equal to the inclination of the axis represented by its plane AB. Make CM and CK equal to the breadth of the level vaults; draw KG and MN parallel to BC, and let MN cut DG in N, and FH in P. Draw the diagonals PG and NH. Produce GK to cut IL in L, and NM to cut IL in Q. In the curve DEF take any number of points *a*, *b*, *c*, and draw *ad*, *be*, *cf* parallel to AB, cutting DF in the points *p*, *q*, *r*, and the diagonal GP in *d*, *e*, *f*, and the diagonal HN in the points *d'*, *e'*, *f'*. Produce BA to E, draw *dl*, *em*, *fn*, B*o* parallel to BC, cutting QL in the points *g*, *h*, *i*, *k*; make *gl*, *hm*, *in*, *ko* equal respectively to *pa*, *qb*, *rc*, AE; then through the points *l*, *m*, *n*, *o*, draw the curve Q*o*L. Draw HR perpendicular to NH, and make HR equal to KL, and join NR; then will HR be the line of ramp for the diagonal rib over its plan HN. Perpendicular to HN, draw *d'v*, *e'w*, *fy*, BG cutting the line of ramp RN in the points *s*, *t*, *u*, *v*. Make *sv*, *tw*, *uy*, *v*G respectively equal to *pa*, *qb*, *rc*, AE. Then through all the points *v*, *w*, *y* draw a curve, which will be the angle rib standing over HN, and which will also serve for the angle rib standing over GP. All the groined vaults continued in the same range may be constructed by the same moulds.

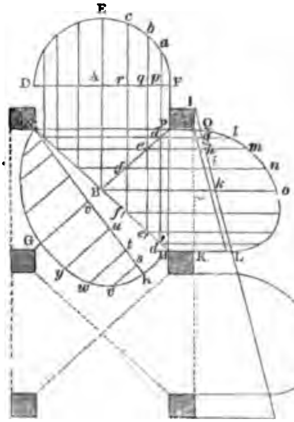


Fig. 646.

1959. *To make the working drawings for a semicircular arch with a straight face, and to describe the moulds for the voussoirs.* This simple case will serve as a rule for those following; hence the explanation should be perfectly understood, as all the other cases differ from it only according to the different kinds of arches to be constructed; such as the *bevelled arch*, that in a *battering* or *sloping wall*, and that on a *circular wall*.

1960. Draw two lines (*fig.* 647.) perpendicular to and crossing each other, as BA, GD From the point E, as a centre, describe the sofite curve ACB, and the extrados or upper curve FGH. Divide each of these arcs into two equal parts, as the dotted arc *abc*. Draw LM parallel to AB, and make the distance A, L equal to the thickness of the wall wherein the arch is to be constructed. Draw the outer and inner lines of the plan F'K, A'L, B'M, HN parallel to CD. Divide the arc ACB into the proper number of equal parts for the arch stones or voussoirs, suppose five, by the joint lines 1, 2, 3, 4; from the point E draw the joints 1—5, 2—6, 3—7, 4—8; then from every point where the joints cut the arcs ACB, FGH, &c. draw the lines 8*c*4, 7*h*3, &c. On KN let fall the perpendiculars 8*d*, *c*M, 4*f*, *hi*, 3*k*, 2*l*, *mn*, 6*o*, 1*p*, *a*L, and 5*s*. Divide the sofite of each voussoir A1, 1—2, 2—3, &c. into two equal parts in *t*, *u*, *v*, *w*, from which all also let fall the perpendiculars *t*Y, *u*X, *v*V, *w*T.

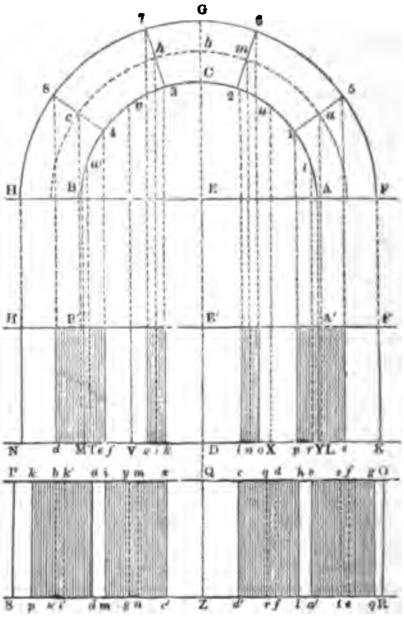


Fig. 674.

1961. *To draw the moulds of the sofite* below NK. Draw the line OP parallel to the line KN; prolong ED to Z and make the distance QZ equal to ED. Through Z draw RS parallel to OP, and on each side of QZ lay off the distances C3, 3*v*, *v*4, 4*w*, and *w*B respectively on Q*x*, *xy*, *ya*, *ab*, and *b*P. On the other side lay off C2, 2*u*, *u*1, 1*t* and *t*A on Q*c*, *cd*, *de*, *ef*, and *f*O. Through the points O, *e*, c, *x*, *a* let fall on RS the perpendiculars OR, *ea'*, *cd'*, *xc'*, *ad*, PS, and through the points *f*, *d*, *y*, *b* let fall the perpendiculars from the middle sheetings *fe'*, *df'*, *yg'*, *bh'*; the distances of the dark lines give the breadth of the sofite of each stone in the sofite curve.

1962. *To draw the moulds of the joints:* lay off the distance 1—5 on *eg*, *ch*, *xi*, *ak*, and through the points *ghin* draw the lines *gq*, *hl*, *im*, *kp*, parallel to QZ. To find the middle of the joint divide the distances *eg*, *ch*, *xi*, *an*, each into two equal parts, as in *k'*, *m'*, *g'*, *s*, through which draw the lines *k'l'*, *m'n'*, *q'r'*, *s't* parallel to QZ.

1963. The elevation is a section of a hollow cylinder, of which the concave or interior surface forms the intrados of the arch, and the convex or exterior surface the extrados, and of which the cutting plane of the section is perpendicular to the common axis of the cylinder.

1964. The angles of the stone are found from the angle which the arc of this section makes with any joint, and the curving of the sofite of the stone is found by a ruler or mould, the edge of which is made to the curve. The ends of the sofite are found by its developement.

1965. When the stones are shaped according to the moulds, and joined together in consecutive order, the whole mass, thus united, will form the solid arch as required.

1966. These separate operations being properly attended to, every difficulty will be removed, and no confusion will arise during the process, which can, in any degree, tend to perplex the delineator.

1967. *To find the bevels and moulds for the joints and sofites of an elliptical arch cutting obliquely through a straight wall, the joints radiating to the centre of the opening.* Draw the axis EN of the arch (*fig.* 648.), and therein take any point E, through which draw AB perpendicular to EN; make EA and EB each equal to half the space of the extrados or centre line of the arch; also make EC and ED each equal to half the span of the inner arch. Produce the diameter NE to G;

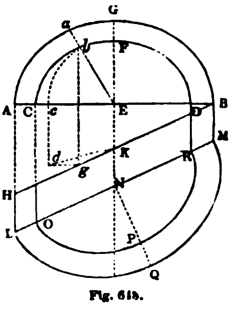


Fig. 648.

make EF equal to the height of the inner arch and EG equal to the height of the outer arch. On the major axis AB, and semi-minor axis EG, describe the semi-ellipsis AGB, which is the extrados of the arch. Also, on CD as the major axis, and EF the semi-minor axis, describe the semi-ellipsis CFD.

1968. Make the angle ABH equal to the angle which the wall makes with the right section of the arch, and let BH cut the axis in K. Draw ML at such a distance from BH that they may comprehend between them the thickness of the wall, and let ML cut the axis in N. The intrados of the arch on the one side of the wall is OPR, and the extrados is LQM; they are both ellipses respectively of the same height as the intrados and extrados of the right arch, but with the axes OR and LM.

1969. *To find the bevel of the angle of the arch stones corresponding to the joint ab tending to the centre* E. Describe the arc *bc* from E with the radius E*b* cutting AB in *c*. Draw *bg* parallel to EN cutting BH in *g*, and draw *cd* parallel and *gd* perpendicular to EN, and join KD; then EKD is the angle or bevel required.

1970. The sofite of the arch is drawn according to the general principles of developement.

1971. *To make the working drawings for an arch in a sloping wall, as, for instance, an arch in a terrace wall.* To draw the elevation; from any convenient point *o* in the line AB (*fig.* 649.), describe the arc of the intrados *a*P*f* and the arc of the extrados AQB: divide each of these arcs into odd numbers of equal parts (for the arch stones in this example five), and draw the joints *bg*, *ch*, *di*, *ek*. For the plan of the arc of the intrados draw AR perpendicular to AB, and draw the line of slope or *batter* AS. In the arc of the intrados take any number of points *bcd*, &c. and draw the lines *bb*, *cc*, intersecting AR in the points 1, 2, &c. and meeting the line of batter AS in the points *bc*. Draw CD parallel to AB, and at any convenient distance from it draw *aubvcw* perpendicular to CD, intersecting it in the points *e*, *l*, *m*, *n*, &c. Find the points *b′*, *c′*, *d′* in the straight lines *bv*, *mw*, *nx*, such that the distance of those points from the line ED may be respectively equal to the intervals 1*b*, 1*c*, &c. between the perpendicular AR and the line of batter AS, and draw the curve *a′ b′ c′ d′ e′ f′*, which will be the plan of the arc of the intrados. In the same manner the curve E*g′h′ik*D may be described; which being done, the plan of the arc of the extrados will be obtained.

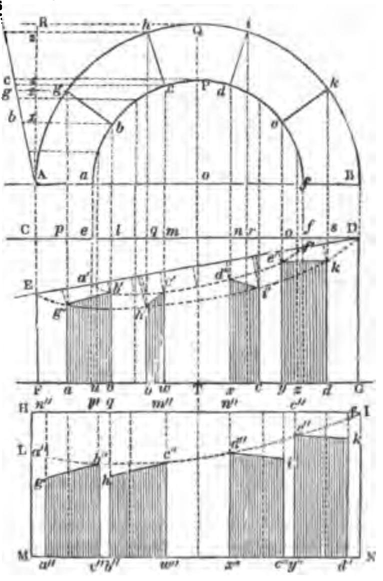


Fig. 649.

1972. *To find the moulds of the sofites and beds.* Draw any straight line HI in a separate place, and extend the arc of the intrados *abcdef* upon the line HI from H to I; divide it into the same number of parts that the arc *a*P*f* of the intrados is divided into (in this instance five), and mark the points of division *l′*, *m′*, *n′*, *c′*. Transfer the distances *ea′*, *lb′*, *mc′* between the line CD and the plan of the arc of the intrados, to the perpendiculars *n″a″*, *l″b″*, *m″c″*, *n″d″*, *c″e″*, and through the points *a″b″c″d″e″f″* draw a curve, which will be the developement of the arc of the intrados. Produce the lines *l″b″*, *m″c″*, *n″d″*, to *v″*, *w″*, *x″*, and transfer the distances *b′v*, *c′w*, *d′x* from the plan to the sofite on the lines *b″v″*, *c″w″*, *d″x″*. Draw *ga″*, *hb″*, *ic″*, *kd″* perpendicular to HI; transfer the distances *g′a*, *h′b*, *i′c* from the plan to the sofite upon *ga″*, *hb″*, *ic″*, and join *a″v″*, *b″w″*, *x″c″*, which will complete the moulds of the joints.

1973. *To make the drawings for an oblique arch by an abridged method.* The following method is said to be abridged, because, by one very short operation the moulds of the sofites and joints are found within the plan of the arch ABDC (*fig.* 650.). Divide AB in E into two equal parts, and draw EF parallel to AC. From the point A draw AG perpendicular to AC; prolong DB to G; divide AC into two equal parts in the point H. From H, as a centre, describe the arc AFG, which divide into voussoirs, and draw the joints from the centre H. Draw lines from each sofite parallel to EF, and below the line CD; the moulds for the sofites are comprised between the parallels of the key, and those of the joints are traced on the sides of the plan, as follows: —

1974. *To find the moulds of the sofites.* Through the point Q draw QN parallel to GH. To find on RS the point N, through the point K draw KL also parrallel to GH. To find on QT the point M, and on RS the point L, draw the front line of the second sofite

MN, and the front line of the first IL. The back of this sheeting sofite is found by the same operation below the plan. The mould of the key is formed by two lines RS, QT, and the front and back lines of the plan AB, CD; the two moulds of the sofites NMTS and LIXV serve to trace the two stones on each side, observing only that the lower arrisses of the sofite on the side AC become those of the top on the side BD; or that the under arriss of one side may be that on the other side by reversing the mould, which will have the same effect.

1975. *To find the moulds of the beds or joints.* Prolong NQ to meet DG, to find the point P, and through it and the point E draw the front of the second joint P2; prolong LM to GD to find O, through which and the point E draw the front of the joint O3. Proceed in the same manner to find the backs of the other joints, which are sufficient also to trace the stones by reversing them. It is not absolutely necessary to cut out the moulds of the sofites and joints, but the angles may be taken by bevels and applied to stones. The heads are prepared, as usual, with the moulds of the heads of the straight arc. It must be observed, that in this arch the face or front differs from a straight arch, being formed by different sections of a cylinder.

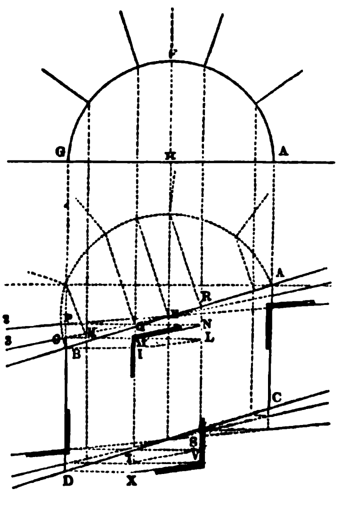


Fig. 650.

1976. *To find the moulds for an oblique arch, whereof the front slopes and the rear are perpendicular to the axis.* Let A'B'GH (*fig.* 651.) be the plan of the imposts. From the point a', as a centre, describe the arcs ACB, DRI, which divide into five or more equal parts for the arch stones. Draw the joint lines from the centre, and the perpendiculars from the joints below the line AB. From the summits of the perpendiculars, draw lines parallel to AB, to terminate in the perpendiculars DF. From the point D, as a centre, describe arcs from the points which terminate in DF, to meet the line of slope DE in the points m, l, k, E. Draw the lines mr, ls, kt, EF parallel to AB, meeting the perpendicular DF in the points rstF; transfer the distances rm, tk, uP from n to b', from o to c', from a' to s', and through the points A$'b'c'd'e'$B$'$ draw the curve. Find the extrados or outer line D$fghi$ in a manner similar to that in which the inner curve has been found. Draw the joints $b'f$, $c'g$, $d'h$, $e'i$. Prolong AH and BG to K and L, and draw the lines $b'b$, cc, $d'd$ parallel to AK.

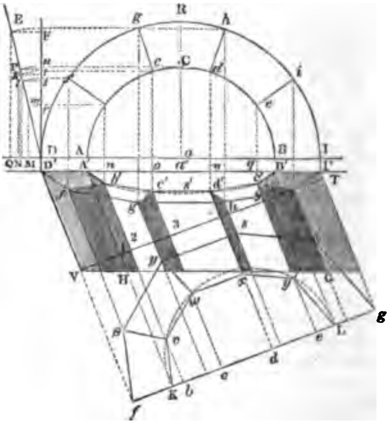


Fig 651.

1977. *To make the straight arches.* Draw KL perpendicular to AK, and produce KL to f and g. Transfer the distances between the points m, l, k, D, and the line QD to the ordinates of the lower arc from b to v, from c to w, from d to x, and from Q to Y, and draw the curve K$vwxy$L. Also find the outer curve in the same manner, and draw VT at right angles to AH.

1978. *To find the moulds of the sofites.* Draw the line WX (*fig.* 652.) in any convenient surface, and lay the breadths of sofite, not from the arc ACB as before, but from those of the right arc K$vwxy$L, that is, transfer the distances Kv, vw, wx, xy, yL to the line WX upon Wa, aa, βb, $gy\delta d$, and δX. Through the points W$abgd$X, draw the lines ny, ei, fk, gl, hm, δz, perpendicular to

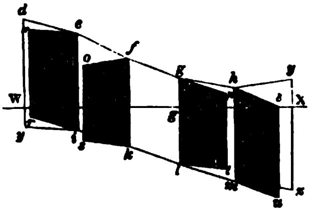


Fig. 652.

WX. Transfer the distances 1A, 2*b*′, 3*c*′, 4*d*′, 6B upon the perpendiculars to WX. From W*n*, from *a* to *e*, from *b* to *f*, from *c* to *g*, from *d* to *h*, and from X to *v*, and join *ne*, *ef*, *fg*, *gh*, *hv*. In the same manner draw the line *yiklmz*, which will complete the sofites.

1979. *To find the moulds of the joints.* Transfer the distances $v\beta$, $w\gamma$, $x\delta$, $y\epsilon$, on the line XW from *a* to α, from *b* to β, from *c* to γ, and from *d* to δ, and through the points α, β, γ, δ draw the lines *ny*, *os*, P*t*, δu perpendicular to WX. Find the points *n*, *o*, *p*, *q*, as also *r*, *s*, *t*, *u*, as in the preceding examples; then the moulds of the joints will be *eirn*, *fkso*, *htig*, $h\delta ug$. It must be observed that the boundaries, or extrados and intrados, DRI, ACB of the ring of the arch, do not stand in a plane perpendicular to the plan, but are supposed to be the lines which are drawn on the wall itself; and this is the reason why arcs are described between the perpendiculars DF and the line of slope DE. It must also be observed, that the voussoirs of this arch must be cut by the moulds of the heads of the straight arch, and the moulds of the sofite must be applied on the voussoirs before the sofite is hollowed. Thus, let the first voussoir on the right hand be cut by the head mould on that face of the stone intended for the sofite; apply the first sofite mould, and its upper bed the first joint mould, and on its under bed the plan of the impost. Then cut the two heads according to these moulds, and hollow the sofite square to its arrisses, using for this purpose the curved bevel.

1980. *To find the moulds for executing a semicircular-headed arch in a mass of masonry, of which one of its faces is a battering plane upon an oblique plan, and the other opposite face a portion of a cylindric surface.* Describe the intrados and extrados of the elevation; draw the joints and describe the plan *a*′*b*′*c*′*d*′*e*′*f*′ of the intrados (*fig.* 653.), and the plan E*g*′*h*′*i*′*k*′D of the extrados. Draw BR′ perpendicular to AB, and draw BS′, the portion of the cylindric surface. From the arc BS′ draw the plan *a*′*l*′*m*′*n*′*o*′*f*′ of the intrados upon the line TU, and the plan T*p*′*q*′*r*′*s*′U of the extrados in the same manner from the arc BS, as the plan of the plane face was drawn from the line of slope AS.

1981. *To find the plan of any joint*, as that for the line or joint *ch* in the elevation. Bisect *ch* in *v*, draw *cm*′, *vw*′, and *hq*′ perpendicular to AB, intersecting the line VD in the points *quc*. From the points *cvh*, in the joint *ch*, draw *cc*, *vv*, *hh*, meeting the line AS in the points *cvh*, and intersecting the line AR in the points 1, 3, 2 by three intervals, 1*c*, 3*v*, 2*h*. Find the places *hvc* of the three points *hvc* on the elevation. In the same manner find the places *q*′*w*′*m*′ of the three corresponding points; then will *c*′*v*′*h*′*q*′*w*′*m*′ be the plan of the joint required. The plans of the other joints will be found in the same manner.

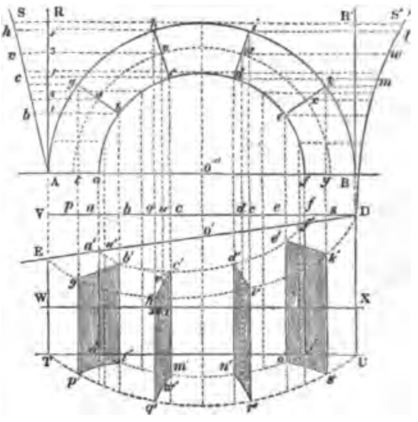


Fig. 653.

1982. *To find the joint mould itself.* Draw the line HI (*fig.* 654.) equal in length to the developement of the intrados, and let H*c* be the developement of the arc *ac*; draw *cm*″ perpendicular to HI. Draw any line WX in the plan parallel to VD, intersecting the lines *c*′*m*′, *v*′*w*′, *h*′*q*′, in the points 1, 2, 3. Draw W′X′ in the developement or sofite parallel to HI, and at the same distance from HI that WX is from VD in the plan, and let WX intersect the line *c*″*m*″ in 1. Make the distances 1—2, 2—3 respectively equal to *cv*, *vh*, in the joint *ch* in the elevation, and through the points 1, 2, 3, just found,

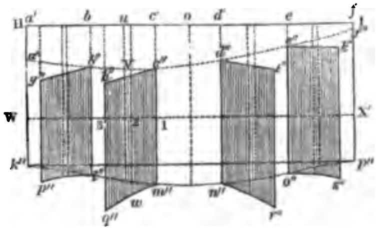


Fig. 654.

draw VW, *h*″*q*″, parallel to C′*m*″. From the plan transfer the distances 2*v*′, 2*w*′, 3*h*′, 3*q*″ to the sofite from 2 to V, and from 2 to W; also from 3*h*″ and from 3 to *g* the points *cvp*″ will be in a straight line, because they correspond to the straight face of the wall, and the points *m*″, *w*, *q*″ will be in a curve, because they correspond to the cylindric surface. Draw, therefore, the straight line *c*″*h*″, and draw the curve line *m*″*wq*″, which will be a portion of an ellipsis, differing in its curvature but in a very small degree from that of a circle drawn through the same three points. However, if more exactness be required, we may find as many points in the joints of the surface of the wall and in the cylindric surface as we please; then $c''m''p''h''$ is the joint required, which serves for the upper and under beds of the two stones that unite together in that joint.

1983. Find all the other joint moulds $b''l''p''g''$, $d'n''v''t''$, $e''o''s''k''$, in the same manner, and find the points $a''f''$ in the developement. Through the points $a''b''c''d''e''f''$ draw a curve line by hand, or by a ruler bent to the points, and this will be the front curve of the sofite. Find the points $k'p''$ in the developement corresponding to the points a' and f on the plan, and through the points corresponding to the points a' and f on the plan, and the points $k''l'm''n''o''p''$, draw another curve, which will be the developement of the other side of the sofite. The developements of each of the parts of the sofite and of the two adjacent joint moulds give the three moulds for working one stone and the adjacent joints of the stone on each side of it. The angle which each of these joints makes with the sofite is found by making a bevel with one of its edges, circular for the intrados of the arc of the elevation, and the other to coincide with the joint line adjacent.

1984. *To find the moulds for executing a gateway in the quoin of a sloping wall.* Let ABCD (*fig.* 655.) be the plan of the angle in which the arch is to be constructed, whereof AB is the span. Draw the centre line EL, to which draw the perpendicular FG. Prolong the line CA to F, and DB to G; then from the point L, as a centre, describe the sofite FHG and its extrados. Divide these arcs into equal parts for the arch stones, and from the divisions let fall perpendiculars, and also from the middle of the sofites to EC, ED. From the summits of the perpendiculars draw lines parallel to FG terminated by the lines of slope. Set off the slope at the different heights *a*1, *a*2, *a*3, *a*4 respectively at right angles to the lines on the plan, on *d*1, *b*2, *d*3, *b*4, K5; also on the opposite side lay *a*2, *a*4 on *d*2, *b*4; then on one side draw the curve A*bb*K, and on the other, to abridge the work, join B*b*, *bb*, *b*K. Again, for the outer curve, or extrados, set off *c*1, *c*2, *c*G on *di*, *d*2, N3. On both sides draw the curve M*dd*O on the one side, and to abridge the labour, draw the straight lines O*d*, *dd*, *d*N.

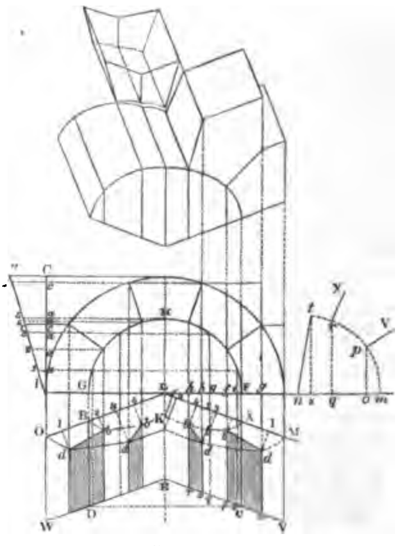


Fig. 655.

1985. *To find the moulds of the sofites.* Draw the line PQ (*fig.* 656.), on which lay the arc of the sofite FHG in the usual manner, making the points 1, 2, 3, which correspond to the points dividing such arc into equal parts; then on the lines of the sofite lay the distances FA, *fb*, *gb*, *hb*, LK, on PR, 1*k*, 2*l*, 3*m*, 4*m*, QS, and trace the front curve of the sofite R*klmn*S. Also repeat the same on the other side where there is only a straight line drawn from one sofite curve to another.

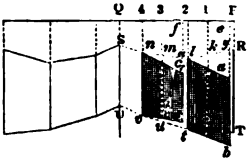


Fig. 656.

1986. *To find the back curve of the sofite.* Lay the distances *eo*, *fp*, *gq*, *kr*, LE on PT, 1*o*, 2*t*, 3*u*, 4*v*, QU, and trace the curve T*otuv*U.

1987. *To find the moulds of the beds or joints.* The sofite lines to which the beds belong are 2*t* and 4*v*. Draw the straight lines *eb*, *fd* parallel to QU, respectively distant from 2*t*, 4*v* by the breadth GI of the joint, and let the lines *be*, *fd* meet PQ in *e* and *f*; make *ea* equal to *gd*, and *ab* equal to *dw*, and join *al*, *bt*; make *fc* equal to *hd*, and *cd* equal to *dx*, and join *nc*, *vd*. To trace the stones by moulds, prepare the voussoirs with the head of the moulds of the straight arch FHG. The sofite should be hollowed in each voussoir by its particular mould: the rest is done as usual; but it must be observed, that if the sofite moulds are made with straight lines in front and near the sofite, it must not be hollowed till the last. The voussoirs may be worked by bevels, preparing the stones by the plans ACVM, BDWO, as for common imposts. Although the arch in each front be not absolutely necessary here, we shall give the method of constructing it. Let the line *mn* be drawn apart, on which lay the distances L5, L4, L2, LA on the lines *ns*, *nq*, *no*, *nm* square to *mn*. Draw the perpendiculars *op*, *qr*, *st*, on which lay the heights of the joints of the straight arch taken on the line of slope; that is, lay I2, on *op*, I4 on *qr*, I5 on *st*, and draw the line *nt*, which is the slope. Then draw the curve *mprt*, and from the point *n* draw the joint lines *pv* and *r*X. The centre of this gate is represented (in the upper part of the diagram) with voussoirs, and the keystone placed behind to show the mitre of the centre. The sofite moulds serve for curving the ends of the stone where the intrados meets the surface of the two walls. It must, however, be observed, that, previous to the application of the sofite mould, the concave surface of the intrados must be formed by a mould with a convex edge, and then the sofite mould or moulds of developement must be bent into the hollow, so that the two parallel edges may coincide with the corresponding edges of the stone. The angles which the intrados makes with the joints are taken from the elevation of the face of the arch. This elevation is no more than a section of the arch perpendicular to the axis of the cylinder which forms the intrados.

1988. *To construct a semicircular-headed arch in a round tower or circular wall.* Let ABDC (*fig.* 657.) be the plan of the tower. Bisect the arc AB, and through the point of bisection draw EF parallel to the jamb line AC or BD. Through any point *a* in EF draw GH perpendicular to EF. Produce the lines CA and DB to meet GH in the points G, H, and GH will be bisected in *a*. From *a*, as a centre, and with the radius *a*G or *a*H, describe the semicircular arc GFH. Also describe the arc of the extrados and divide the arcs each into five equal parts, and let fall the perpendiculars of the joint lines, and those of the middles of the sofite curves to the inside circular line CED of the tower. Having extended the arcs of the intrados curve on the line IK, and having drawn the lines of the sofites and those in the middle of each sheet as before directed, lay off the distances between the right line GH and the circular outside line A*b*B, viz. GA on IX and on KZ, *cd* on *ef*, V*g* on *hi*, S*k* on *lm*, M*n* on *op*, *ab* on *qr*; then trace the front curve on the sofite X*r*Z. To find the rear curve, lay GC on IY, *c*C on *e*S, &c., by which the rear curve will be obtained.

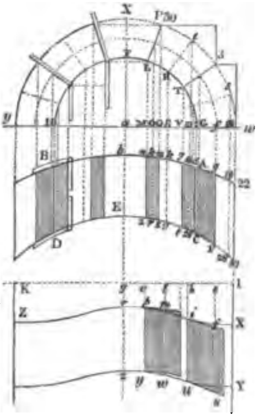


Fig. 657.

1989. We do not consider it necessary to pursue the construction of the moulds, the operations being very similar to those already given in the previous examples.

1990. *To find the moulds for an oblique semicircular arch in a circular tower.* The construction of this differs from the preceding only in the bevel or obliquity of the tower; hence it requires no particular description; only observing, that the bevel causes the mould to be longer on one side than on the other (see *fig.* 658.), as is evident from the plan; therefore the distances taken between the right line AB and the circular line of the tower CDE, being unequal, must be transposed each on its particular line of the mould and joint to which it corresponds in the sofite, that is, the distance AC must be laid on FG, BE on HI, and so of the rest. To work the stones, dress the beds, then apply the proper moulds and cut the head and tail circular as before. Trace the breadth of the sofite on the upper bed, then hollow the sofite, and cut the joints by the bevel.

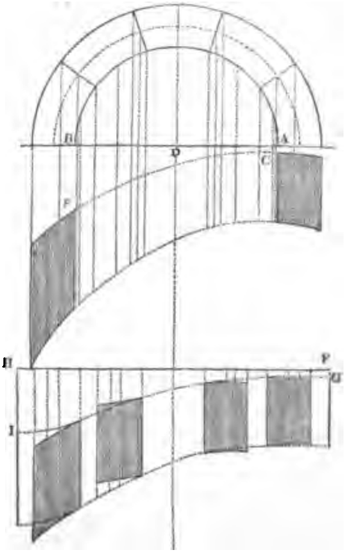


Fig. 658.

1991. *To construct an oblique arch in a round sloping tower intersecting a semicircular arch within it.* This is nearly the same as the two preceding cases. On one side draw the line of slope (*fig.* 659.) AB, and on the other the arc CD. Draw parallels from the divisions of the sofites and their middles, as in the figure, in order to cut the line of slope and arc. To work for the slope, set off all the retreats comprised between the perpendiculars AH and the line of slope AB on the perpendiculars of the sofite, square to the front line of the tower F 19 G, as follows: Transfer the retreat 9—10 on 19—20 by placing the compasses so that the line 19—20 would pass through the centre of the tower, and the point 20 fall on the centre of the gate O—75, and 7—8 on 17—18, and on 21—22 in the same manner (only terminated by the lines from the sofite instead of the centre line of the arch), set also 5—6 on 15—16, and on 23—24, 3—4 on 13—14 and on 25—26, and lastly 1—2 on 11—12 and on 27—28, and through these points trace the sofite 28—20—11. The extrados is found in like manner, and the middles of the joints 47, 49, 53; which done, draw the plan of the joints 14—47—35, 18—19—37, 22—51—39, and 26—53—41.

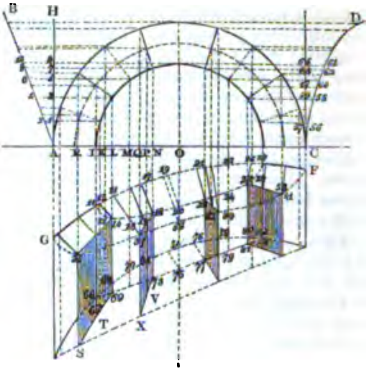


Fig. 659.

1992. *To find the curve of the plan which terminates the tails of the moulds.* Set the projections of the buttress of the semicircular arc at right angles to the inside line of the tower; viz. 64—65 on 74—75; 62—63 on 72—73 and on 76—77; 60—61 on 70—71, and on 78—79, 58—59 on 68—69, and on 80—81; 56—57 on 66—67 and on 82—83; then trace by hand the curve 83—75—66. The curves of the extrados and joints are found in the same manner.

1993. *To find the moulds of the sofite.* Draw the line of direction 94—84 (*fig.* 660.) as before, below which set off the distances I—11 or 84—85, K—12 on 86—87, L—14 on 88—89, M—16 on 90—91, N—18 on 92—93, O—20 on 94—95, and then trace the front of the sofite moulds 85—95—99. To find the rear, set I—66 on 84—33, K—67 on 86—36, L—69 on 88—100, M—71 on 90—98, N—73 on 92—97, O—75 on 94—96, and trace the rear curve of the mould 101—96—33.

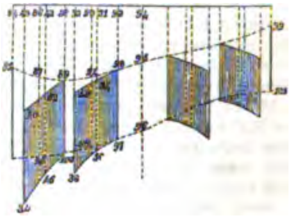


Fig. 660.

1994. *To find the moulds of the joints.* Transfer P—19 on 31—54, Q—37 on 32—48, I—47 on 42—52, R—35 on 43—40, and through these points trace the front joint or bed moulds 93—54—48, 89—92—40. To find the rear, make 31—50 equal to PV, 32—38 equal to QX, 42—46 equal to IT, and 43—34 equal to RS; which done, trace the curve lines 97—50—38 and 100—46—34. The two other joints are found by the same method. We do not consider it necessary further to multiply examples of the kind here given: the latter sort, especially, rarely occur in practice; and if they should, all that will be necessary to master the operations will be the application of a little thought and study.

1995. III. Of Dome Vaulting. In whatever direction a hemispherical dome is cut, the section A is always the same. B represents one half (see *fig.* 661.) of the same in the plane of projection. The construction is sometimes such that the plan is only a semicircle, as B, as in the termination of the choir of a church: in which case the French call it a *cul-de-four;* with us it is called a semi-dome.

1996. Through the extremities of the joints, and through the middle of each sofite of the section A, let fall on the line *ab*, perpendiculars, whereof all the distances *dc* from the centre *c* will be the radii of the arcs, which will serve for the developement of the sofites, of the joints, and for the construction of the arch stones. The method which follows, though it will not perhaps give the sofites and joints strictly accurate, will do so sufficiently for all practical purposes. Upon the developement C make SC equal to the arc MDGC, then set out to the right of the points of division the parts ST equal to *st* on the plan B; then raise through the points T upon the line SC perpendiculars equal

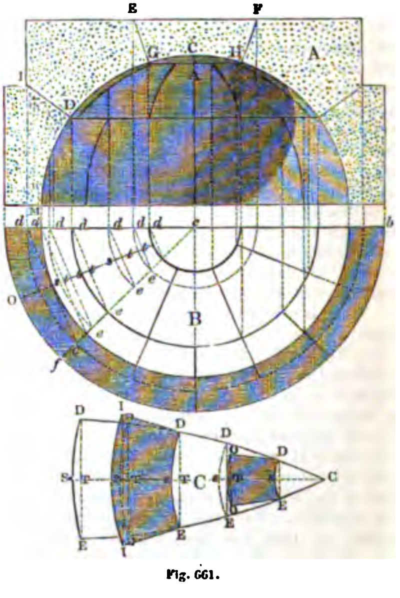


Fig. 661.

to the correspondents *e*, *t*, *d* of the plan B, and draw the curve ESD through the points so found.

1997. The sofites are terminated by four curves, whereas the joints have two right sides, as DI, EI, and DO, EO, and two curved sides, as II, DE, and OO, DE; the widths DI, DO of the joints are equal to DI, GE of the section; in one direction they are curved only one way, but as respects their sofites they are so in every way. The heights of the voussoirs are given by the section A, their bases on the plan B. Thus G, I, in the voussoir next the keystone, being the most opposite points, the base of it on the plan will be comprised between the two arcs *dte*, which answer to the perpendiculars let fall from G and I. The base of the first voussoir, according to the first method, will be equal to the surface comprised between the arc *aof* and the arc *dse*, which answers to the perpendicular let fall from the point D.

1998. EF and GH are the diameters of the upper and lower bases of a truncated cone, whose lower surface is hollowed out spherically. After working the voussoirs, so as to make their bases such as we have just indicated, they must be worked to sofite moulds for giving them the hemispherical form of the section; after which the angles of the moulds are joined by arcs parallel to the arrisses of each stone, or by applying a general mould of the form of the section, that is, circular, of the radius of the dome.

1999. *For the pendentives formed in an hemispherical dome.* The piers D and E are supposed those of half the dome pierced by the pendentives. If we suppose the face or elevation B (*fig.* 662.) to make one quarter of a revolution about the point A, we obtain the elevations B and C. Through the points of division on the elevation C draw to the arc AD right lines perpendicular to CA. On the extremities of these lines upon CA, and from C, as centre, describe arcs in the plan F, by which the plan of the projection on F is obtained, whose intersections with the right lines drawn from B will give the joints and faces for the level beds. The lines HF, FE, ED are right lines. The spaces GAEF, FHIK are pieces of cylindrical vaulting, so that the only difficulty is in joining to each of their voussoirs their correspondent parts in ELMHFE.

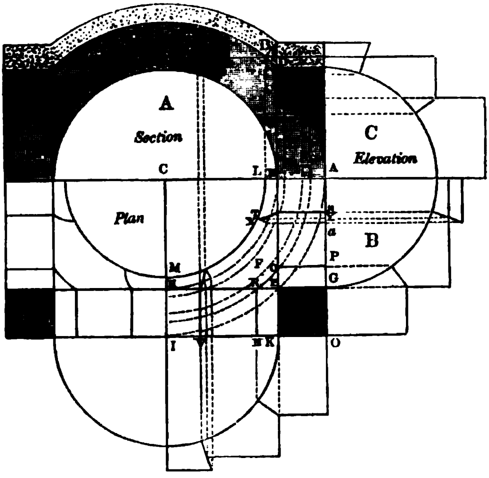


Fig. 662.

2000. The elevation B gives the height of the voussoirs; their bases, as seen in the preceding example, will be OPQRNO, GSTUVKFG. The length of the keystone will be XY, and *a*—A will be half its width.

2001. The part FQR is the plan of the springing stones of the pendentive in the elevation A. The remaining parts of the construction are sufficiently shown by the lines of the diagram, which will be understood by the student if he has previously made himself acquainted with the previous portions of this section.

2002. We should willingly have prolonged this part of our labours, if space had permitted us to do so without sacrificing other and important objects. If the subject be one in which more than the ordinary practice of the architect is called upon to put into execution, we refer him to Simonin, *Coupe des Pierres*, Paris, 1792, and Rondelet's *Art de Bâtir*, which we have used with much freedom, and in which many more interesting details will be found than we have thought it absolutely necessary here to introduce, though we believe we have left no important point in masonry untouched. We cannot close this section without paying our tribute of respect to the masons of this country, who are among the most intelligent of the operative builders employed in it. A very great portion of them are from the north of the island, and possess an astuteness and intelligence which far exceeds that of the other classes of artisans. We must not, however, altogether do this at the expense of those employed in carpentry, which will form the subject of our next section, among whom there will be found much skill and intelligence, when the architect takes the proper means of drawing it out; and we here advise him never to be ashamed of such means.

Sect. IV.

PRACTICAL CARPENTRY.

2003. Carpentry is the science of framing or letting into each other an assemblage of pieces of timber, as are those of a roof, floor, centre, &c. It is distinguished from joinery in being effected solely by the use of the *axe*, the *adze*, the *saw*, and the *chisel*, which are the carpenter's tools; whereas joinery requires the use of the plane.

2004. Though necessarily of high antiquity, the very scanty information which Pliny and Vitruvius have left us on the subject would merely show that the science was known by the ancients. The roofs of Egypt present us with no more than flat coverings of massy stone; a pediment roof, therefore, would seem to have been among the first efforts of constructive carpentry; and upon the pitch which this, then and since, has received in different countries, we shall hereafter have to speak. The Greeks appear to have used carpentry in the construction of their floors and some other purposes; but in a country abounding with stone and marble, it is not likely that wood was much used in the interiors of their buildings, unless where lightness, as in doors, for instance, required its employment. With the Romans it was much more commonly used; and from all that can be gathered, we may consider them as the fathers of the science.

2005. Among the moderns it has been very successfully cultivated; and, with very few exceptions, we may almost assert that the works of Palladio, Serlio, Delorme, Sir Christopher Wren, Perronet, and a few others, exhibit specimens which have scarcely been surpassed in later times, notwithstanding the scientific form it has assumed in the present age.

2006. To the mechanical principles of carpentry we have, in Chap. I. Sect. XI. of this Book, directed the attention of the student; and to the section now under our pen we should have added the heading *Descriptive* to *Practical Carpentry*, but that much of what could have been said on that head has already been anticipated in our section on Descriptive Geometry. Hence, in what follows, that which comes under such predicament will be only given in particular cases, for the purpose of saving time and trouble to the reader in the application of its principles to them. We must, here, also remind the reader, that under the section of Mechanical Carpentry have been described the different sorts of timber used for building purposes, their strengths, and the strains to which they are subject and which they are capable of resisting; and that therefore this section is confined simply to putting pieces of timber together, so as to form the assemblage of timbers under which we have commenced by defining the science. To do that properly requires great skill and much thought. Considerable waste, and consequent expense to the architect's employer, result from that ignorance which assigns to the scantlings of timber larger dimensions than are absolutely necessary for the office of each piece; insufficient scantlings will bring the architect into trouble and responsibility; and the improper connection of the pieces will be equally ruinous to his reputation. The principles of practical carpentry are, nevertheless, simple; and though to form new combinations and hazard bold and untried experiments in practice will require all the skill and science of a talented artist, the ordinary routine of carpentering is to be learnt by a little application and a due exercise of common sense.

2007. After these observations, we must introduce the student to the first operation which in practice may arise. It is not every where that timber can be obtained in sufficient lengths to stretch across the void he has to cover; and it will in such cases be necessary for him to know how one piece of timber may be so joined to another, for the purpose of lengthening it, that the two pieces, when joined, may be as nearly as possible equal in strength to one whole piece of timber of the same dimensions and length. This operation is of great service to the builder, and is technically called *scarfing*. To perform it, the joints are indented, and bolts are passed through the pieces within the length of the indents, such bolts being confined above and below by means of nuts and screws. In *fig.* 663. four ways are exhibited of accomplishing the object in question. A and B are the methods usually employed for joining together plates, lintels, and ties, in which bolts are rarely necessary; but if such a method is used for scarfing beams, bolts must be employed. The stronger forms, which only should be used for beams, shown in C and D, are not only in that respect such as should, on that account, be used for beams, but are executed without loss of length in the pieces of timber. The length of the joints of the scarfing may be increased at pleasure; the diagrams are merely given to show the mode of doing what was required. With fir, however, when bolts are used, about four times

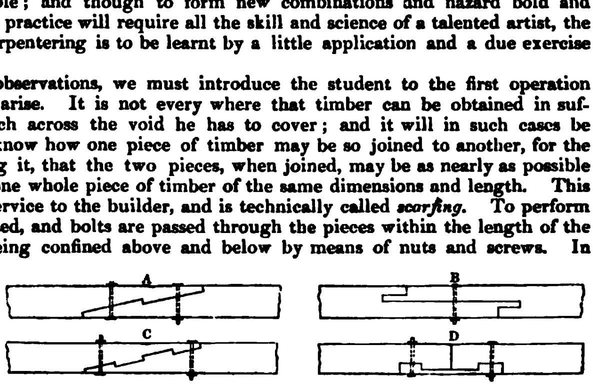


Fig. 663.

the depth of the timber is a usual length for a scarf. Scarfing requires great accuracy in execution; for if the indents do not bear equally, the greater part of the strength will be lost: hence it is improper to use very complicated forms for the indents.

2008. Pieces of timber are framed into and joined to one another, by the aid of *mortices* and *tenons*, and by iron straps and bolts; and on the proper placing of these depends the soundness of the work. If a piece of framing is to stand perpendicularly, as in the case of partitions, without pressure from either side, the mortice and tenon should be in the centre of the wood. But in the case of framing floors, in which the pressure is on the upper surface, and entirely on one side, the mortices and tenons ought to be nearest the side on which the pressure is, by which the timber will not be so much weakened; and hence it is the constant practice to cut the mortices and tenons as in *figs.* 664, 665. By the method shown in the last-named figure, the tenon obtains more strength from an additional bearing below, which is further increased by the inclined butment above, called a *tusk*.

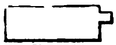


Fig. 664.

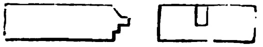


Fig. 665.

2009. The method of framing wall plates together at an angle, for the reception of the hip rafter on the *dragon beam*, and the angle ties for retaining the wall plates in their places, is shown in *fig.* 666., wherein AB is the mortice cut for the tenon of the hip rafter shown in *fig.* 667. *Fig.* 668. is one of the wall plates, showing the halving to receive the other plate, and the cutting necessary for dovetailing the angular tie. *Fig.* 669. shows the method of cutting the mortices and tenons of principal and hip rafters; another method being given in *fig.* 670., and to be preferred where a greater resistance to thrust is sought, because by it a double *butting* is obtained on the tie beam. Inasmuch, however, as in this last case the beam is cut across the grain to receive the rafter, the part left standing to receive the heel of the rafter may be easily split away; to obviate which, the socket may be cut, as at A, parallel to the grain of the wood. *cd* is the iron strap for securing the rafter's foot to the tie beam, and keeping it in its place. A plan of the upper part of the tie beam is given at B, showing the socket and mortice of the section A in the last figure. C exhibits the mode in which a king-post is strapped to a tie beam, with the *struts* and *joggles*.

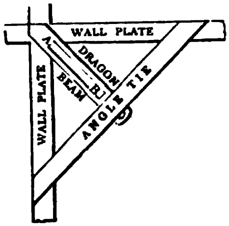


Fig. 666.

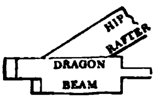


Fig. 667.

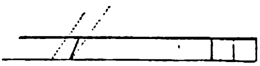


Fig. 668.

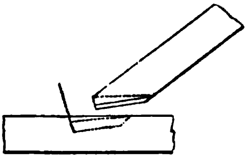


Fig. 669.

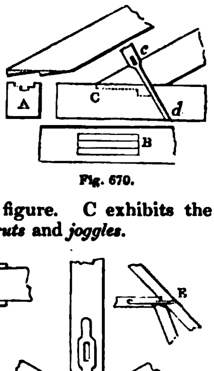


Fig. 670.

2010. The most approved method of forming butments (*fig.* 671.) for the *struts* or *braces*, *aa*, which are joggled into the king-post, is to make their ends, which act against the joggle, perpendicular to the sides of the brace; they will thus be kept firmly on their butments, and have no tendency to slide. C is a section of the king-post and tie beam, showing the mode of wedging and tightening the strap, with a single wedge, in order to draw the tie beam close to the king-post. D is a section of the same parts to a larger scale, and with the introduction of a double wedge, which is easier to drive than a single one, because there is less action upon the cross grain of the wood.

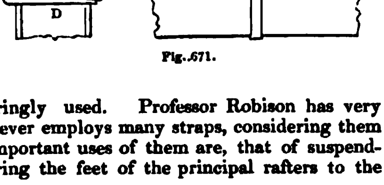


Fig. 671.

2011. Straps in carpentry should be sparingly used. Professor Robison has very properly observed, that "a skilful carpenter never employs many straps, considering them as auxiliaries foreign to his art." The most important uses of them are, that of suspending the tie beam to the king-post, and of securing the feet of the principal rafters to the tie beams in roofs.

2012. Bolts are sometimes used for the last-named office, with *washers* and heads and screw nuts, in which case the washers, nuts, and heads should be well painted, though even then they are liable to rust. Wherever the iron work used for securing a system of framing is exposed to the humidity of the atmosphere, it should be rendered durable by frequent painting. Price (*British Carpenter*, 1759) observes thus: "There is one particular that had liked to have escaped my notice, concerning the placing of iron straps on any truss, thereby meaning to help its strength, which is by turning the end square (as shown at E, *fig.* 671.). This method embraces the timber in such a manner, to make it like a dovetail, *which cannot draw from its place;* another observation is, to bolt on your straps with square bolts, for this reason: if you use a round bolt, it must follow the auger, and cannot be helped; by this helping the auger-hole, that is, taking off the corners of the wood, you may draw a strap exceeding close, and at the same time it embraces the grain of the wood in a much firmer manner than a round pin can possibly do." The example given by Price, however, for turning square the strap, is injurious to the rafter, which must be partially cut to admit of it.

FLOORS.

2013. The assemblage of timbers in a building, used for supporting the flooring boards and ceiling of a room, is, in carpentry, called *naked flooring*, whereof there are three different sorts, viz. *single flooring*, *double flooring*, and *double-framed flooring*. But before entering on the particulars of either of the sorts, we will make some general observations on the construction of floors, which require the architect's attention. First, the wall plates, that is, the timbers which lie on the walls to receive the ends of the girders or joists, should be sufficiently strong and of sufficient length to throw the weight upon the piers. Secondly, if it can be avoided, girders should not lie with their ends over openings, as doors or windows; but when they do, the strength of the wall plates must be increased. To avoid the occurrence in question, it was formerly very much the practice in this country, and indeed is still partially so, to lay girders obliquely across rooms, so as to avoid openings and chimneys, the latter whereof must indeed be always attended to. Thirdly. Wall plates and templets must be proportionately larger as their length and the weight of the floor increases. Their scantlings will, in this respect, vary to 4½ by 3 inches, up to 7½ by 5 inches. Fourthly. The timbers should always be kept rather higher, say half to three quarters of an inch higher, in the middle than at the sides of a room, when first framed, so that the natural shrinking and the settlement which occurs in all buildings, may not ultimately show when the building is finished. Lastly, when the ends of joists or girders are supported by external walls whose height is great, the middles of such timbers ought not at first to rest upon any partition wall that does not rise higher than the floor, but a space should, says Vitruvius (lib. 7. c. 1.), be rather left between them, though, when all has settled, they may be brought to a bearing upon it. Neglect of this precaution will induce unequal settlements, and, besides causing the floor to be thrown out of a level, will most probably fracture the corners of the rooms below.

2014. Single Flooring is constructed with only one series of joists (as shown in *fig.* 672.). In this way of framing a floor, if a girder is used, it should be laid as nearly as possible over the centre of the apartment. A *single* floor containing the same quantity of timber as a double floor is much stronger; but the ceiling of the former is liable to crack, and cannot be got to so good a surface when finished. Hence, where the bearings are long, it is much better to use double flooring.

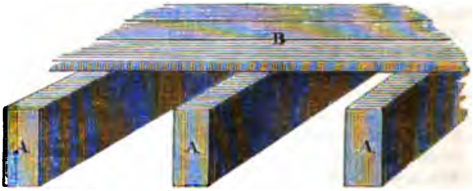


Fig. 672.

2015. The scantlings of fir joists for single flooring are exhibited in the subjoined table, and are founded on our own practice. The weight of a square varies from 11 to 18 cwt.

Length in Feet.	Width in Inches.	Depth in Inches.
6	2	6
8	2½	7
10	2½	7½
12	2½	8
14	2½	9
18	2½	12
20	3	12

These scantlings may be varied if wanted, according to the laws laid down in the section on Mechanical Carpentry. (1622. *et seq.*)

2016. In *fig.* 672. A A A are the joists, and B the floor boards. The laths for the ceiling are nailed to the under side of the joists A A A.

2017. In most floors, on account of the intervention of flues, chimney openings, and occasionally other causes, it will so happen that the ends of the joists cannot have a bearing on the wall. In such cases a piece of timber called a *trimmer* is framed into two of the nearest joists (then called *trimming joists*) that have a bearing on the wall. Into the trimmer, which is parallel to the wall, the ends of the joists thus intercepted from tailing into the wall are mortised. The operation is called *trimming*. The scantlings of trimmers and trimming joists may be the same as those hereafter given for binding joists; or if to the width of the common joists an eighth of an inch be added for each joist supported by the trimmer, the depth being the same, the scantling will generally be sufficient.

2018. When the bearing of a single joist floor exceeds 8 feet, a row of strutting pieces should be introduced between the joists, by which they will be prevented from horizontal twisting, and the floor will be stiffened. If the bearing be more than 12 feet, two rows of stiffening pieces or struts should be introduced, and so on for each increase of 4 feet in bearing. They should be put in, in continued rows, and be well fitted. Beyond a bearing of 15 feet it is not advisable to use single flooring, neither ought it in any case to be used where it is required to prevent the passage of sound.

2019. A *double floor* consists in its thickness of three tiers of timbers, which are called *binding joists* (these perform the office of girders), *bridging joists*, and *ceiling joists*. From an inspection of *fig.* 673. the construction will be easily understood. AA are the binding joists, which are the principal support of the floor on the upper side, whereof BB, the bridging joists are notched; which is the best method, though sometimes they are framed between with *chased mortices*. The binders, of course, run from wall to wall; and as for carrying the floor, the bridging joists, as their name imports, are *bridged* on to them; so the lower tier of timbers, called the *ceiling joists*, are either notched to them, or are what is called *pulley mortised* into them; that is, a chase is cut in the binder long enough to allow of the tenons of the ceiling joists being obliquely introduced into them and driven up to their places. The scantlings of timbers used in this method are the same as those for doubled-framed flooring, of which, indeed, it is but a species.

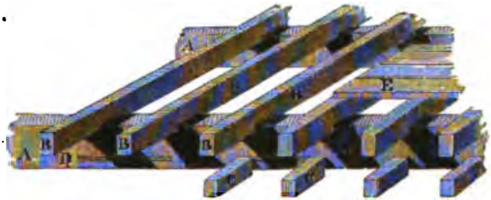


Fig. 673.

2020. The *double-framed floor* differs only from the last-named by the binding joists, instead of going from wall to wall, being framed into large pieces of timber called *girders* (as shown in *fig.* 674.), wherein A is the girder, B a binding joist, C a bridging joist, D a ceiling joist, E the pulley mortice for the ceiling joist D, and F is the floor. The great advantages of this sort of flooring are, that it prevents the passage of sound between the stories, and enables the architect to make a solid ceiling.

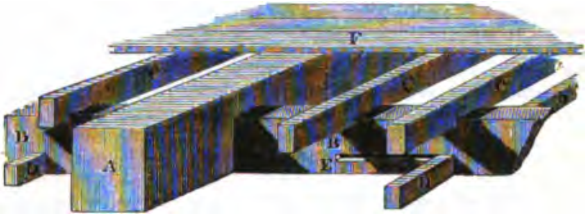


Fig. 674.

2021. As in a double-framed floor the girders are the chief supports, it is exceedingly important that they should be sound and free from shakes. The distances between one girder and another, or the wall, should not exceed 10 feet, and their scantlings as in the following table: —

Girders of the length of 10 feet	should be	9 inches deep,	7 inches wide.
12	—	10	8
14	—	11	9
16	—	12	10
18	—	12	11
20	—	13	11
22	—	14	12
24	—	15	12
26	—	16	12
28	—	16	13
30	—	16	14

Girders whose bearing exceeds 24 feet are difficult to be procured of sufficient depth, in which case an expedient is put in requisition to strengthen a less depth. The principles it involves will be explained under the head of Roofs, namely, those of *trussing* them, an operation which converts the girder within its own thickness into a piece of framework, for the purpose of preventing the bending, or as it is techically called, *sagging*, of the girder, which produces an injurious horizontal thrust on the walls. This operation is represented in *fig.* 675. in two different ways, the lower portion of the diagram representing the plan.

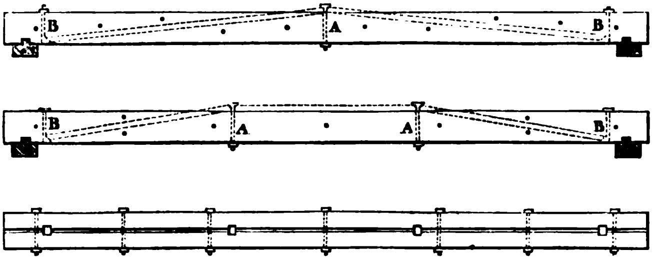


Fig. 675.

The girder is cut into two halves in the direction of its depth and length, between and into which the truss is inserted, as shown. It is better that the *truss posts* A, and *abutment pieces* B, should be of wrought iron; the *struts* C may be of oak, or some stiffer wood than the girder itself.

2022. We now return to the subject of binding joists, which ought not to be more than 6 feet apart. The depths, if necessary, for accommodating them to the thickness of the floor, may be varied from the following table by the rules already given under the section Mechanical Carpentry.

Binding joists of the length of	6 feet should be	6 inches deep,	4 inches wide.
8	—	7	4½
10	—	8	5
12	—	9	5½
14	—	10	6
16	—	11	6½
18	—	12	7
20	—	13	7½

The scantlings of bridging joists are similar to those already given for single flooring. These, as well as ceiling joists, whose scantlings are subjoined, should not be more than 12 inches apart, and they require to be scarcely thicker than is necessary to bear the nails of the laths fixed to them, for which 2 inches is quite sufficient.

Ceiling joints of the length of	4 feet should be	2½ inches deep,	1½ inch wide
6	—	3½	1½
8	—	4	2
10	—	5	2
12	—	5½	2½

The weight of a square of framed flooring with counter flooring varies from 22 to about 36 cwt.

2023. Though, perhaps, more curious than useful, we should not perform our duty to the student, were we to omit a method of constructing floors with short timbers, where long ones are not to be procured. Suppose it be required to floor the room ABCD (*fig.* 676.)

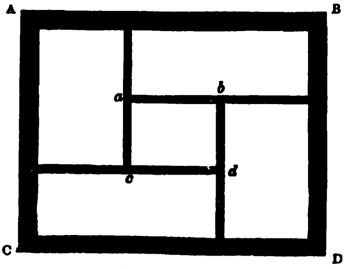


Fig. 676.

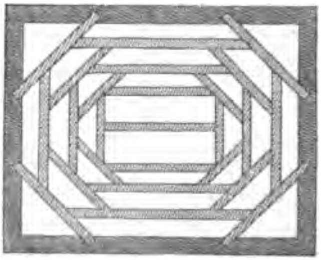


Fig. 677.

Let four joists, as in the figure, be mortised and tenoned at *abcd*, as there shown. Now it is evident that these joists will mutually support each other, for each is supported at one end by the wall, and at the other by the middle of the next joist. *Fig.* 677. shows another mode of accomplishing the same object; and many other forms would immediately suggest themselves to the experienced architect. The expedient is of ancient origin, inasmuch as our old master (so we delight to call him, notwithstanding the new lights that modern critics have found to guide them), Serlio, has described the expedient without any difference. In the fourth volume of Rondelet (*Art de Batir*), an author to whom we are under infinite obligations, is described a floor executed at Amsterdam for a room 60 feet square, of exceedingly singular construction, inasmuch as it is without joists at all. Each side of the room is provided with very strong wall plates, whose angles are secured with iron straps, and are rebated to receive the flooring, which consists of three thicknesses of 1½ inch boards. Of these thicknesses, the first is laid diagonally across the opening, its ends resting on the rebates of the wall plates, and rising about 2½ inches towards the centre of the room. The next (second) thickness is laid diagonally at right angles to the first thickness, and the two are well nailed together. In the third thickness, the boards are laid down parallel to one of the sides of the room, and form the upper side of the floor, being, however, well nailed to those below. The whole of them are *grooved* and *tongued* together, forming a solid floor 4½ inches thick. In this example is an instance well worthy the study of the architect, as respects a scientific connection of parts, and the great advantage of a well-disposed bond. The floor in question is, in fact, a thin plate, well supported round the edges, the strengths of the plates being directly as the squares of their thicknesses, equally strong to bear a weight in the middle, whatever their bearing; though if the load be uniformly distributed, the strength will be inversely as the area of the space.

PARTITIONS.

2024. The framework of timber used for dividing the internal parts of a house into rooms is called a *partition* or *quartered partition*. It is commonly lathed and plastered; when the spaces between the timbers or quarters are bricked up, it is called a *bricknogged partition*. The weight of a square of common partition is rarely less than from 13 to 18 cwt.; hence it becomes necessary to take care that partitions should not be set upon the floor, without taking due precaution to relieve it of the weight, either by struts, braces, or the formation of a truss in it. When a partition occurs in an upper story, under a strongly trussed roof, it may be often advantageously suspended from the roof, and its weight thus taken off from the floor below. If it have a solid bearing throughout its length, it requires nothing but struts between the quarters; but these are not absolutely required. The scantlings of the timbers of a quarter partition should vary according to the extent of bearing. Where that does not exceed 20 feet, 4 by 3 inches will be sufficient; and where it is as much as 40 feet, the quarters should not be under 6 by 4 inches, that is, supposing it to bear only its own weight. When it has to bear more, the scantling must, of course, be increased accordingly.

2025. *Fig.* 678. represents a design for a trussed partition, with a doorway in the centre of it: in which *hh* is the head, and A A the sill; *dc*, *dc* the doorposts; *gg* the *intertie*, A*d*, A*d* the braces; *fd*, *fd* struts. *Fig.* 679. shows a method of trussing a partition in which the doors are at the sides. It is obvious that additional strength may also be gained, when wanted, by introducing a truss between the intertie and head of a partition. The angle of inclination of braces should be about 40° with the horizon.

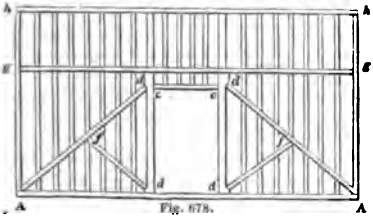


Fig. 678.

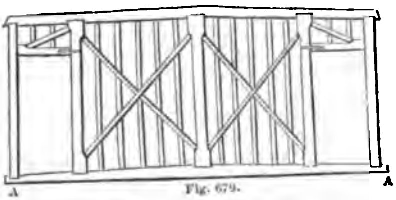


Fig. 679.

CARRIAGE OF STAIRS.

2026. The framed timbers which support the steps of a staircase are called the *carriage*. They generally consist of two pieces inclined to the pitch of the stairs, called the *rough strings*. When geometrical stairs consist of two alternate flights with a half-pace between them, the carriage of the half-pace is constructed with a beam parallel to the risers of the to press upon the walls, and by that bearing to unite and hold all together. This it will not be massy enough to perform if too little timber be employed, so that the extreme is to be shunned. But in practice the great and common error is on the other side; and he will do the most acceptable service to his profession, who shall show how to retrench and execute the same roof with a smaller quantity of timber; he will by this take off an unnecessary load from the walls, and a large and useless expense to the owner."

2031. We shall now proceed to a popular view of the strains exerted by the timbers of roofs, referring the reader back to the section on Mechanical Carpentry for a more extended and scientific view of them. Suppose (*fig.* 680.), in the simplest form of roof, the rafters (shown by dotted lines) AB, CB to pitch upon the walls A*a*, C*c*. Let the rafters be supposed to be connected together at B as by a hinge, as also similarly connected with the walls at A and C. Now if the effective weight of the walls be not sufficient to resist the thrusts of the rafters, as respects the height, thickness, and situation of the centre of gravity of such walls, taken as solid masses and moveable on the points X and Y, it is manifest the rafters by their own gravity will descend, and the walls will spread and be thrown out of an upright, as in *ab* and *cd*, and the rafters will take the places shown in the figure. It has already (Mechanical Carpentry, 1633.) been shown that the horizontal thrust of a pair of rafters thus meeting each other, is proportional to the length of a line drawn perpendicularly from the rafter's foot until it intersects a vertical line drawn from its apex. As the roof therefore becomes flatter, the length of the perpendicular increases. Hence, if AB and BC be the rafters, and their weights be represented by their lengths, the weight or power of thrust exerted by the rafter AB in the direction of its length will be represented by BO, and the horizontal thrust by AO; AO being perpendicular to AB. To secure, then, the walls in their perpendicularity, which the thrust of the rafters tends to produce, a system of framing becomes necessary. Thus, in *fig.* 681., a beam AC, which from the office it performs of tying or confining the feet of the rafters is called a *tie beam*, is introduced across the opening, and into this beam the rafters are framed. If the tie is introduced above the level of the walls, it is called a *collar beam*, as *ac*. It is manifest that these beams exert their power in the same way that a string would, that is, that the principal strain which they have to perform is in the direction of their length, and hence, that for such especial purpose, if they be prevented from *sagging* or bending, a small size or scantling will be sufficient, for we have already seen that the cohesive power of timber is very great in the direction of its length. To take care that the tie beam thus introduced should be strained only in the direction for which it is used, we are now led to another expedient. The beam by its own gravity, especially in a large opening, would have a tendency to sag or bend in the middle, and the more so if its scantling be simply proportioned to its office of a tie. To prevent this a fresh tie is introduced called a *king-post* DB (*fig.* 682.), by which the beam is tied or slung up to the apex of the principal rafters; and this combination of a pair of rafters, a tie beam and a king-post, is called a *truss*, and is the most important of the assemblages which the carpenter produces. When the rafters are of such length that they would be liable of themselves to sag down, supports *aa* are introduced at the points where such failures would occur, and these supports are called *struts*, because their office is to strut up the rafter, which they should do as nearly as the case will admit in a direction perpendicular to the slope of the rafters.

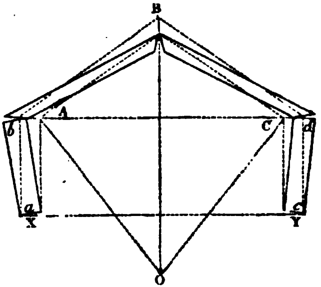


Fig. 680.

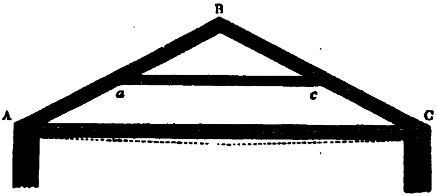


Fig. 681.

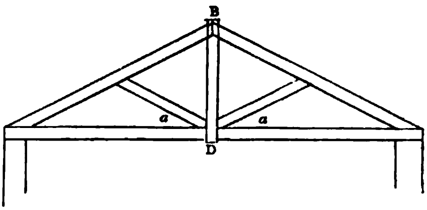


Fig. 682.

2032. It is clear that out of this last case a fresh system of trusses may arise as in *fig.* 683., for from those points procured by the struts against the rafters, new rods may be slung for increasing the stiffness of the tie beam *ad infinitum* in theory, but not in practice, because the compressibility of the fibres of timber is considerable in lines perpendicular to their direction, and the contraction and expansion of metal places a limit to its use. This compression of timber deserves great attention on the part of the architect. We may lay down as a rule in respect to it that the more the weights or pressures act in the direction of the fibres, the less will be the compression.

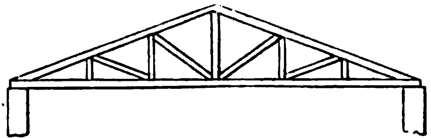


Fig. 683.

2033. To exemplify this, *fig.* 684. shows in No. 1. the principal rafters of a roof butting in an ordinary roof, against the shoulders AB, CD of the kingpost, whose fibres, being vertical, are compressed by the pressure against it, on each side of the rafters, whereby they approach each other, causing the whole figure of the roof to suffer a change. For by the action of compression and its consequence the kingpost must descend, and with it, consequently, the tie beam which is slung up to it. To remedy the inconvenience in roofs constructed of fir, the kingpost is often made of oak, which is less compressible, a practice which should be observed in all roofs of consequence. But cast iron kingposts are the best substitute where the expense can be justified. In No. 2. the end is accomplished much more economically by *housing* the rafters in the head of the kingpost at the angle in which the rafters meet, by which the fibres of the rafters butt against each other, bringing the compression nearer to that which takes place in a post according as the rafters are less inclined to each other, and the beam is then literally suspended from the vertical planes of the rafters at their junction.

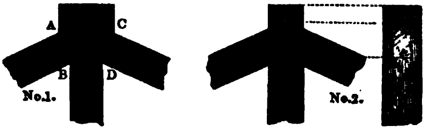


Fig. 684.

2034. When a roof (*fig.* 685.) is trussed by two upright suspending posts, which become necessary in increased spans, such posts, AB, CD, are called *queen-posts*, and the piece between them, BD, is called a *collar*, which acts as a *straining piece* to prevent the heads of the queen-posts moving out of their places towards each other. It will on mere inspection be seen that this roof has three points of support, B, E, and D; for by means of the struts AE, EC, a new suspending point is gained from E for sustaining the tie beam between the points A and C. It is also to be observed that the collar or straining piece BD performs in this assemblage an office exactly the reverse of that which it does in *fig.* 681.

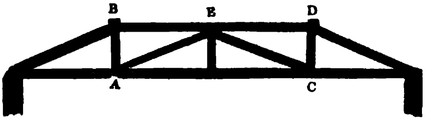


Fig. 685.

2035. The *Mansard* roof, so called from its inventor's name, and with us also called a *Curb roof*, is frequently used for the purpose of keeping down the height of a building, and at the same time of obtaining sleeping or other rooms in it, is shown in fig. 686. It may be considered as primarily consisting of four pieces of timber connected by hinges at the points ABCDE. If these, as shown by the dotted lines, be inverted, they will arrange themselves by their gravity in such a manner that when returned to their first position they remain in a state of equilibrium, which, however, in practice, is but a tottering one, and requires additional expedients to prevent the whole assemblage thrusting out the walls; and, moreover, to prevent the upper rafters from acting by their thrust to displace the lower ones. To obtain these ends the first object is to introduce the tie AE (*fig.* 687.); and, secondly, the tie BD. It is to be understood that means are to be used, when needed from their length, to prevent these beams from bending, similar to those already directed in the cases of simple trusses. We have thus far endeavoured to explain in the simplest way the conduct to be pursued for obtaining stability in the construction of a roof; but

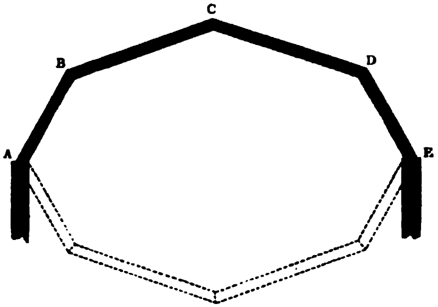


Fig. 686.

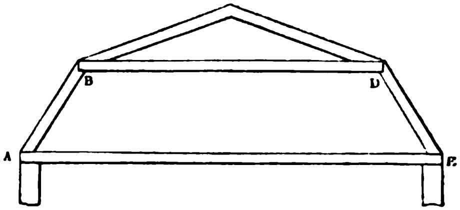


Fig. 687.

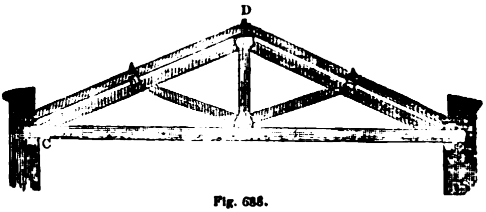


Fig. 688.

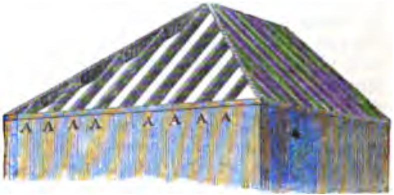


Fig. 689.

before we proceed to the scantlings of the timbers to be employed, the reader must be informed that the trusses to roofing, with whose nature he has now become acquainted, are placed only at certain intervals (which should not exceed 10 feet) apart, and are thus made to bear the *common rafters* and the weight of the covering, as well as to perform the office of suspending the tie beam by which the walls are kept together. Hence the rafters so framed in a truss are called principal rafters; and by the means of a *purline* A (*fig.* 688.), which lies horizontally throughout the roof's length on the principal rafters, they are made to bear all the superincumbent load. The purlines are in various ways made fast to the principal rafters, and upon it the common rafters are usually notched down. Their bearings are thus lessened, and less scantlings suffice for them. They are received at their feet on a piece of timber (B in the figure), which runs longitudinally along the sides of the building. This piece of timber is called a *pole plate*, from being the uppermost plate in a building; at their summits they abut against a *ridge piece* D. When a roof slopes each way, the space enclosed between the intersection of the slopes is called a hip (*fig.* 689.); and the longest rafters in it, which are those at the angles, are called *hip rafters*, and the shorter ones are named *jack rafters*, as A, A, A, &c.

2036. We have, at the beginning of this section (2007.), observed, that the use made of bolts must be always in a direction as nearly as possible counter to the strain which the pieces exert; the method, therefore, of introducing them will, on due consideration, be sufficiently obvious.

Before proceeding to lay before the reader some few examples of roofs suitable to different spans, as well as of some of magnitude which have been executed, it may be as well to complete this portion of our labour, by giving some information on the scantlings of timber for roofing, in which a medium, founded on our own practice, is introduced between ignorant overloading, and fanciful theory.

2037. For roofs whose spans are between 20 and 30 feet, no more than a truss with a king-post and struts will be necessary, in which case the scantlings hereunder given will be sufficient.

For a span of 20 feet, the tie beam to be 9 in. by 4 in.; the king-post, 4 in. by 4 in.; principal rafter, 4 in. by 4 in.; struts, 4 in. by 3 in.

For a span of 25 feet, the tie beam to be 10 in. by 5 in.; the king-posts, 5 in. by 5 in., principal rafter, 5 in. by 4 in.; struts, 5 in. by 3 in.

For a span of 30 feet, the tie beam to be 11 in. by 6 in.; the king-post, 6 in. by 6 in.; principal rafter, 6 in. by 4 in.; struts, 6 in. by 3 in.

2038. For roofs whose spans are between 30 and 45 feet, a truss with two queen-posts and struts will be required, and a straining piece between the queen-posts. Thus —

For a span of 35 feet, the tie beams to be 11 in. by 4 in.; queen-posts 4 in. by 4 in.; principals, 5 in. by 4 in.; straining piece, 7 in. by 4 in.; struts, 4 in. by 2 in.

For a span of 40 feet, the tie beams to be 12 in. by 5 in.; queen-posts, 5 in. by 5 in.; principals, 5 in. by 5 in.; straining piece, 7 in. by 5 in.; struts, 5 in. by 2¼ in.

For a span of 45 feet, the tie beams to be 13 in. by 6 in.; queen-posts, 6 in. by 6 in.; principals, 6 in. by 5 in.; straining piece, 7 in. by 6 in.; struts, 5 in. by 3 in.

2039. For roofs whose spans are between 45 and 60 feet, two queen-posts are required, and a straining piece between them; struts from the larger to the smaller queen-posts, and struts again from the latter.

For a span of 50 feet, tie beams, 13 in. by 8 in.; queen-posts, 8 in. by 8 in.; small queens, 8 in. by 4 in.; principals, 8 in. by 6 in.; straining piece, 9 in. by 6 in.; struts, 5 in. by 3 in.

For a span of 55 feet, tie beams, 14 in. by 9 in.; queen-posts, 9 in. by 8 in.; small queens, 9 in. by 4 in.; principals, 8 in. by 7 in.; straining-piece, 10 in. by 6 in.; struts, 5½ in. by 3 in.

For a span of 60 feet, tie beams, 15 in. by 10 in.; queen-posts, 10 in. by 8 in.; small queens, 10 in. by 4 in.; principals, 8 in. by 8 in.; straining piece, 11 in. by 6 in.; struts, 6 in. by 3 in.

2040. The scantlings of purlines are regulated principally by their bearing; and though we have subjoined scantlings for bearings of 12 feet, such should be avoided by not allowing the distances between the trusses to exceed 10 feet. Thus —

For a bearing of 6 feet, the scantling of the purline should be 6 by 4.
8 feet, — 7 by 5.
10 feet, — 8 by 6.
12 feet, — 9 by 7.

For common rafters the scantlings are as follow; 12 feet should be the maximum of the bearing.

For a bearing of 8 feet the scantling of the rafter should be 4 by 2½.
10 feet, — 5 by 2½.
12 feet, — 6 by 2½.

2041. By a study of the roofs which follow as examples, the architect will be led to other expedients and modifications of the forms submitted to his notice, as circumstances may call forth his ingenuity and talents. We have, we trust, already said enough to lead him on. Where economy must be consulted, the roof shown in *fig.* 690. may be used; it is only fit for a small building, and the span of such a one should not exceed 25 feet. The left end of the collar beam exhibits what is called the *carpenter's boast*, but it partakes somewhat of the rule joint, being worked out to a centre. But in roofs above 25 feet span it is not well to omit the king-post and tie beam, though, if particular strains are to be provided against, even in such small spans the struts should not be omitted, and the form shown in *fig.* 691. should be adopted, which will answer for spans at least up to 35 feet. In this and other cases of larger span, it is often desirable that the common rafters should not stand above the principals, and then the purlines are framed by mortices and tenons into the principals, as shown at A (*fig.* 692.), wherein the line *bc* shows the underside of the common rafters notched on to the principals.

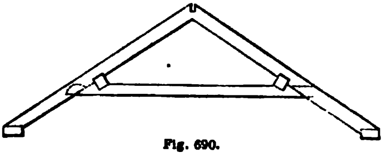


Fig. 690.

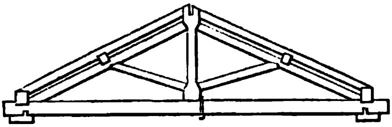


Fig. 691.

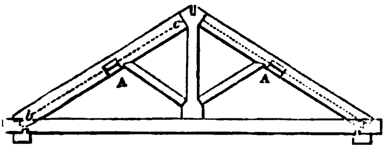


Fig. 692.

2042. From 35 to 45 feet, the tie beam should be suspended from at least three points, or it will be unnecessarily heavy; and this suspension of the tie beam, so that it may be really a tie unsusceptible of alteration in form, is the true cause of this introduction of king and queen posts, as we have before explained to the reader. Indeed, as a general rule, it is well that the distance between such points of support for a tie-beam should not exceed 13 to 15 feet, without expedients being used to prevent intermediate sagging. *Fig.* 693. is the form of a roof for a span of from 50 to 60 feet, in which is seen the connection of the roof with the walls.

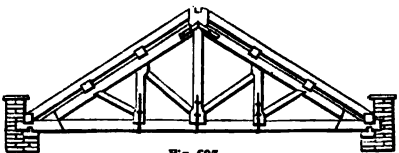


Fig. 693.

2043. For spans above 60 feet we have not given scantlings of timber in the preceding tables; but such do not greatly increase beyond 60 feet with practicable spans, and enough has been already said to make the reader acquainted with that part of the subject. *Fig.* 694. is an example of a roof calculated for a span of 70 to 80 feet, and in *fig.* 695. a passage or other conveniency may be practised between the queen-posts.

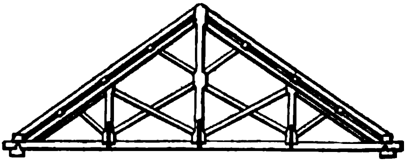


Fig. 694.

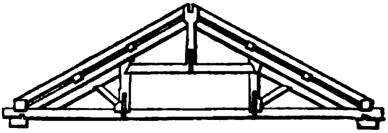


Fig 695.

2044. In all the cases given, the roof is supposed to receive no support from any but the external walls, and the trusses to be not more than 10 feet apart.

2045. We shall now proceed to offer a few examples of roofs that have been executed, all of which have already appeared in works relating to the subject, as specimens of the most instructive and useful class for the student. The reader who desires to extend his inquiry into this branch of carpentry, and to become acquainted with a multitude of examples, is recommended to the celebrated work of Kraaft, *Recueil de Charpente*, and also to Rondelet's admirable treatise *L'Art de Batir*. The space to which we are limited prevents the insertion of many specimens which we would have gladly published here. The principles have, however, been so explained, that we trust the omission will not be felt. In respect of Gothic examples, a reference to the section of Westminster Hall (*fig.* 196.) will exhibit one of the modes adopted to span the large ancient halls of the country. In them the tie is rarely found connecting the feet of the principal rafters; for such an arrangement would have prevented the ornamental system which results from the substitution of a collar for a tie beam.

2046. *Fig.* 696. represents a section of the roof of St. Martin's-in-the-Fields, Westminster, designed by Gibbs. The breadth of the building between the walls is 69 ft.; from centre to centre of columns the middle aisle is 39 ft. 11 in. The roof is well contrived and framed; but the timbers are stronger than they need have been. The scantlings of them are as follow: — A, principal rafter, 13 in. by 10 at bottom, and 11 in. by 10 at top; B, straining brace, 14 in. by 10 at bottom, and 11 in. by 10 at top; C, king-post, 9 in. by 9; D, strut, 7 in. by 7½; E, queen-post, 8 in. by 9½; F, strut, 7 in. by 7; G, tie beam, 14 in. by 9½; H, post over the column, 14 in. by 9½; I, brace, 7 in. by 7; K, brace, 7 in. by 7; L, post, 8 in. by 9; M, hammer beam, 14 in. by 9½; N, brace, 8 in. by 8; P, post in the wall; QQQ, purline rafters, 4 in. by 6.

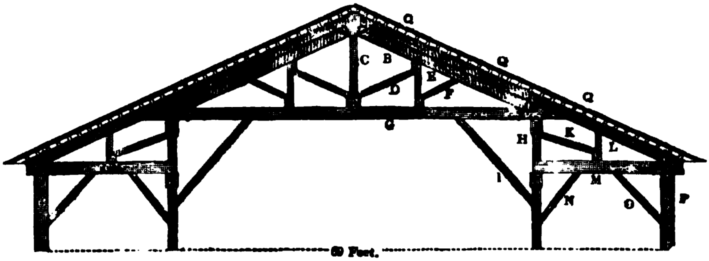


Fig. 696.

2047. *Fig.* 697. is a section of the roof to the chapel of Greenwich Hospital, constructed by Samuel Wyatt, about 1785. The span is 51 ft., and as a variety from the general forms of roofs, it is worth the student's attention. The scantlings of the timbers are subjoined; the distance between the trusses is about 7 feet, and the king-posts are of iron. All the joints are well secured with iron straps. AA, tie beam, whose whole length is 57 ft., 51 ft. clear between the walls, 14 in. by 12 in.; B, an iron king-post, 2 in. square; CC,

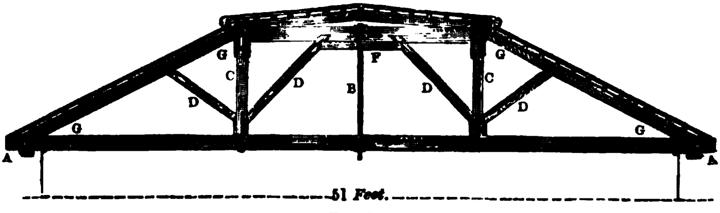


Fig. 697.

queen-posts, 9 in. by 12; DDDD, struts, 9 in. by 7; E, straining beam, 10 in. by 7; F, straining piece, 6 in. by 7; GG, GG, principal rafters, 10 in. by 7; *hhhh*, &c. purline rafters for boarding upon instead of rafters; H, a camber beam, supporting the platform.

2048. *Fig.* 698. exhibits the roof of the old Drury Lane Theatre, which was built in 1793. It possesses great merit, from the simplicity of its composition and the accommodation afforded in the middle space for the carpenters and painters. By dividing the breadth of the building into three parts, the roof was kept low, and the scantlings much reduced in size. The span is 80 ft. 3½ in., the trusses were 15 ft. apart, and the whole length of the roof was 200 ft. It was destroyed by fire on the 24th of February, 1809. The scantlings of the timbers were as follow: — A, beams, 12 in. by 7; B, principal rafters, 7 in. thick; C, king-posts, 12 in. by 7; D, struts, 5 in. by 7; E, purlines, 9 in. by 5; F, ridge pieces, 1½ in. thick; G, pole plates, 5 in. by 5; H, gutter plates framed into beams, 12 in. by 6; I, common rafters, 5 in. and 4 in. by 2½; K, beams, 15 in. by 12; L, posts, 15 in. by 12: M, principal braces, 14 in. by 12 and 12; N, struts, 8 in, by 12; O, oak trusses to the middle bearing of beams, 5½ in. by 4½; P, straining beams, 12 in. by 12.

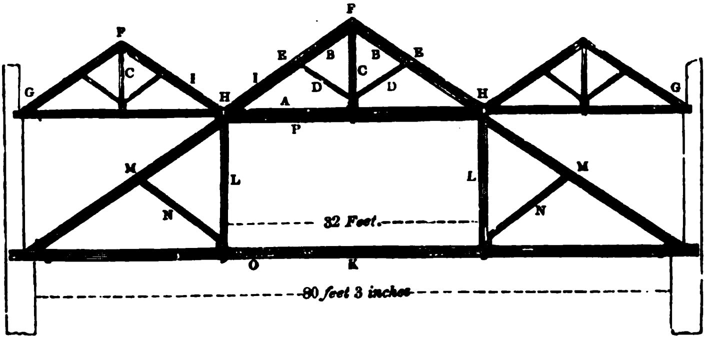


Fig. 698.

2049. The last example we shall present is of the method in which the external dome of St. Paul's is framed (*fig.* 699.). The internal dome A*a* is of brickwork, two bricks thick, having, at every five feet, as it rises, a course consisting of bricks eighteen inches long, which serves to bind the whole thickness together. This dome was turned upon a centre, which rested upon the projection at its springing, without any support from below, and was afterwards left for the use of the painter. It was banded together with iron at the springing. Exterior to the brick dome (which has indeed, nothing immediately to do with the subject) is a cone of brickwork BB*b*, 1 foot 6 inches in thickness, plastered and painted, part whereof is seen from the pavement under the cupola through the opening *a*. On this cone BB*b* is supported the timber work which carries the external dome, whose hammer beams CC, DD, EE, FF are tied into the corbels G, H, I, K with iron cramps, which are well bedded into the corbals with lead, and bolted to the hammer beams. The stairs which lead to the Golden Gallery on the top of the dome are carried between the trusses of the roof. The dome is boarded from the base upwards, hence the ribs are fixed horizontally at near distances to each other. The scantling of the curve rib of the truss is 10 in. by 11½ at the bottom, and 6 in. by 6 at the top. The sides of the dome are segments of circles, whose centres are marked in the figure; and which, if continued, would meet at top, and form a pointed arch. Above the dome rises a lantern of Portland stone, about 21 feet in diameter, and 64 feet high, standing on the cone. The whole of this construction is manifest from the figure, which exhibits the inner and outer domes with the cone between them. The combination is altogether an admirable example of the mathematical skill and judgment of Sir C. Wren.

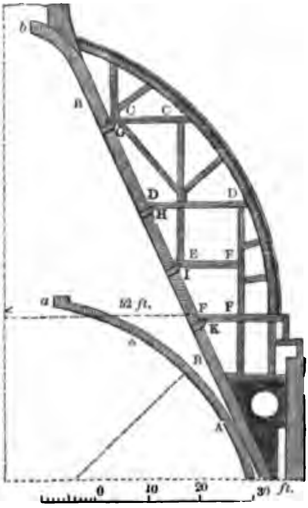


Fig. 699.

2050. The largest roof that was, perhaps, ever executed, was over a riding-house at Moscow, built in 1790, by Paul I. Emperor of Russia, the representation whereof may be seen in Kraaft, *Recueil de Charpente*. The span is 235 feet, and the slope with the horizon about 19 degrees. The external dimensions of the building were 1920 feet long by 310 feet wide. It was lighted by a lantern at top, and had an interior gallery round the building for spectators. The contrivance is exceedingly ingenious; but, from the great extent of the span, considerable settlement took place, and alterations, or rather strengthening ribs, became necessary.

2051. We shall close this part of the section with a diagram (*fig.* 700.) of the roof of the basilica of S. Paolo fuorì le murà, executed in the fifteenth century. The trusses are double, each consisting of two similar frames, nearly 15 inches apart, at intervals from each other of about 10 feet 6 inches. The principal rafters abut on a short-king post *k*. Between the trusses a piece of timber S is placed and sustained by a strong key of wood passing through it and the short king-posts. This piece sustains the beams by means of another strong key at *a*. The tie beams are in two lengths, and scarfed together, the scarf being held together by three iron straps. The scantlings of the timbers are as follow: beams *t*, 22¼ in. full by nearly 15 in.; principal rafters *p*, 21¾ in. by nearly 15 in.; auxiliary rafters *b*, full 13¾ in. by full 13¼ in.; straining beam C, near 15 in. by full 12¾ in.; purlines *d*, 8¼ in. square and 5 ft. 7 in. apart; common rafters, full 5¼ in. by 4¼ in., and 8¼ in. apart. The roof, which is constructed of fir, is nearly 78 ft. 6 in. span, and is covered with the Roman tile, the exact dimensions and form whereof will be found, under the head Tile, in the Glossary appended to this work. The roof is ingeniously and well contrived, and, with a different covering, would suit other climates. It was consumed by fire about two or three and twenty years ago. (275.)

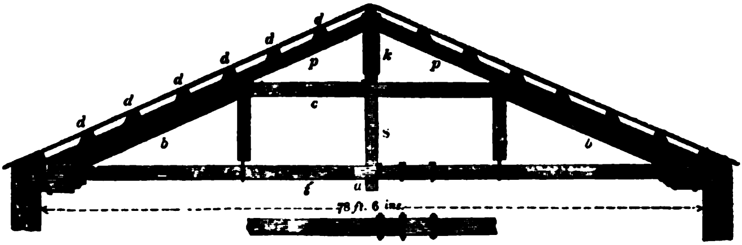


Fig. 700.

Philibert Delorme, in his work entitled "*Nouvelles Inventions pour bien bâtir a petits Frais*," Paris, 1561, gives a mode of constructing domes without horizontal cross ties, when the springing of each rib is well secured at the foot. It is a very simple method, and of great use in domes, even of large diameter, the principle being that of making the several ribs in two or more thicknesses, which are cut to the curve in lengths not so great as to weaken the timber, and securing these well together by bolts or keys, and observing especially to *break* the joints of the several thicknesses. This method was adopted in the large Halle aux bleds at Paris, which was many years since destroyed by fire, and has been replaced by an iron-ribbed dome. The *fig.* 701. will explain the construction; and, if necessary, an iron hoop passed round at different heights will add much to the strength.

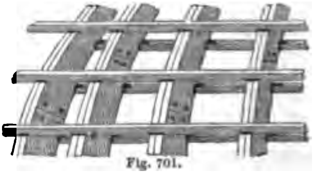


Fig. 701.

2052. The scantlings of the ribs, as given by Delorme, are as under: —

For domes of	24 feet diameter, the ribs to be	8 in. deep, and 1 in. thick.
	36 feet diameter,	—	10 in. deep, and 1¼ in. thick.
	60 feet diameter,	—	13 in. deep, and 2 in. thick.
	90 feet diameter,	—	13 in. deep, and 2¼ in. thick.
	108 feet diameter,	—	13 in. deep, and 3 in. thick.

The work of the author from which we have given this short and summary account deserves the study of every one that seeks to be an architect, though in these unfortunate days for the art the reward of study and reading is very doubtful; patronage being of much more importance to the professor than a profound knowledge of construction and design.

2053. The following instructions relative to the lines necessary to be found in the framing of roofs are from Francis Price's *British Carpenter*; and though published long since, now nearly 100 years, we have not found that any subsequent work on this particular point gives us more information than is to be there found. Let *abcd* (*fig.* 702.)

be a plan to be inclosed with a hipped roof, whose height or slope is Cb. Divide the plan lengthwise into two equal parts by the line *ef*, which produce indefinitely at both ends. Make *ag* equal *ea*, and *dk* equal to *df;* and through *k* and *g*, parallel to *ab* or *cd*, draw lines indefinitely *mo*, *lp*. With the distance dc or Cc, either of which is equal to the length of the common rafters, set off *qe*, as also from *h* to *p*, from *i* to *o*, and from *f* to *n*; from *k* to *m*, and from *g* to *l*. Make *ts* equal to Cb, and *ab* equal to *ta*, which points join; then either aC or *as* represents the length of the hip rafter, and joining the several lines *aqb*, *bpoc*, *cnd*, and *dmlu*, they will be the *skirts* of the roof.

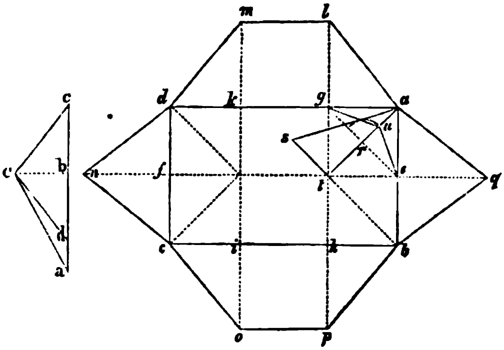


Fig. 702.

2054. To find the back of the hip. Join *ge*, and from *r* as a centre describe an arc touching the hip *as*, and cutting *at* in *u*. Then join *gu* and *ue*, and *gue* is the back of the hip rafter required.

2055. *Fig.* 703. represents, in *abcd*, the plan of a building whose sides are bevel to each other. Having drawn the central line *ef* indefinitely, bisect the angle *rag* by the line *ae*, meeting *ef* in *e*. From *e* make *eg* equal to *re*, and *rg* perpendicular to *ea*; then, if e a be made equal to *ea*, ra or *aq*, it will be the length of the hip rafter from the angle *a*. Through *e* and *f*, perpendicular to the sides *db*, *ca*, draw the lines *np*, *mq* indefinitely; and from *a*, as a centre with the radius *aq*, describe an arc of a circle, cutting *mq* in *q*, and *er* (perpendicular to *ba*) produced in *l*. By the same kind of operation *oc* will be found, as also the other parts of the skirts of the roof. The lines *nt*, *tfv*, and *vp* are introduced merely to show the trouble that occurs when the beams are laid bevel. The angle of the back of the hip rafter, *rwg*, is found as before, by means of *u* as a centre, and an arc of a circle touching *aq*. The backs of the other hips may be found in the same manner.

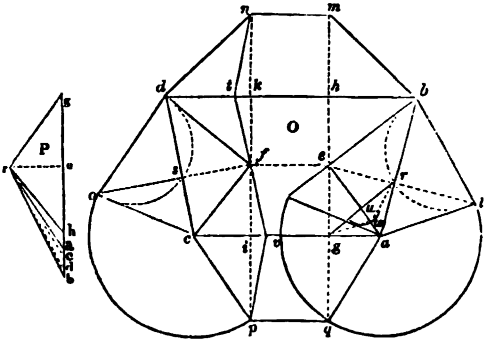


Fig. 703.

2056. *Fig.* 704., from Price's *Carpentry*, is the plan of a house with the method of placing the timbers for the roof with the upper part of the elevation above, which, after a perusal of the preceding pages, cannot fail of being understood. The plan F is to be prepared for a roof, either with hips and vallies, or with hips only. The open spaces at G and H are over the staircases: in case they cannot be lighted from the sides, they may be left to be finished at discretion. The chimney flues are shown at IKLMNO. Then, having laid down the places of the openings, place the timbers so as to lie on the piers, and as far as possible from the flues; and let them be so connected together as to embrace every part of the plan, and not liable to be separated by the weight and thrust of the roof. P is a trussed timber partition, to discharge the weight of the roof over a salon below.

2057. Q is the upper part of the front, and R a pediment, over the small break, whose height gives that of the blank pedestal or parapet S. Suppose T to represent one half of the roof coming to a point or ridge, so as to span the whole at once, "which," as Price truly observes, "was the good old way, as we are shown by Serlio, Palladio," &c., or suppose the roof to be as the other side U shows it, so as to have a flat or sky-light over the lobby F, its balustrade being W; or we may suppose X to represent the roof as spanning the whole at three times. If X be used, the valley and hip should be framed as at Y; if as T, the principal rafters must be framed as at Z, in order to bring part of the weight of the roof and covering on the partition walls. The remainder needs not further explanation.

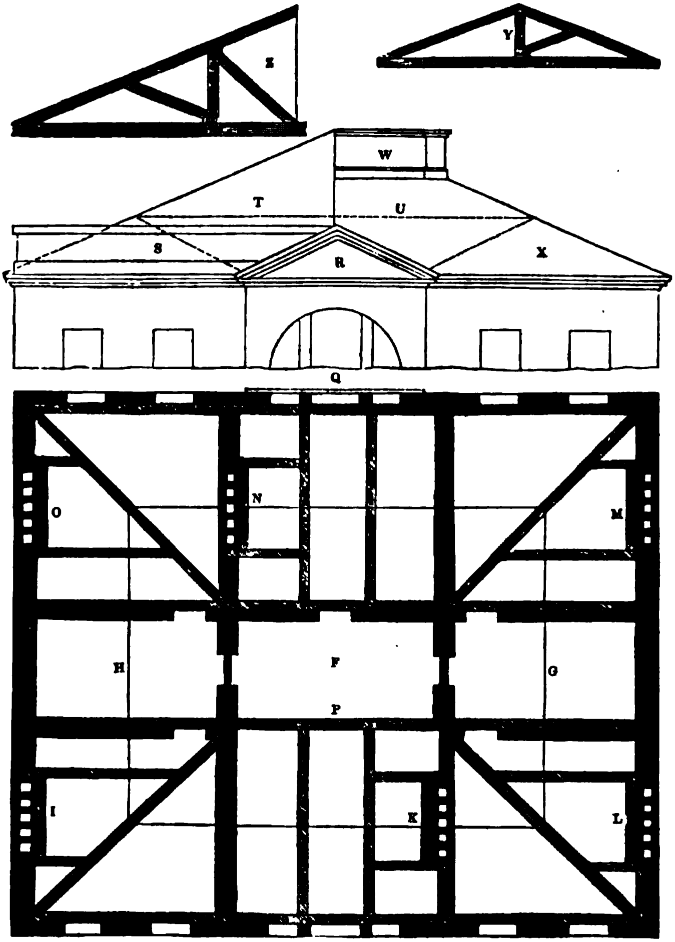


Fig. 704.

RIBS FOR GROINS, ETC.

2058. We shall now proceed to the method of forming the ribs for groined arches, niches, &c. The method of finding the shape of these is the same, whether for sustaining plastering or supporting the boarding of centres for brick or stone work, except that, for plaster, the inner edge of the rib is cut to the form, and, in centering, the outer edge. Groins, as we have already seen, may be of equal or unequal height, and in either case the angle rib may be straight or curved; and these conditions produce the varieties we are about to consider.

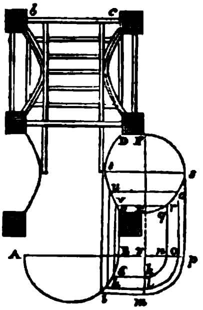


Fig. 705.

2059. *To describe the parts of a groin where the arches are circular and of unequal height, commonly called* WELSH GROINS. We here suppose the groin to be right-angled. Let AB (*fig.* 705.) be the width of the greater arch. Draw BD at right angles to AB, and in the straight line BD make CD equal to the width of the lesser arch. Draw DF and CE perpendicular to BD and EF parallel to BD. On AB describe the semicircle B*ghi*A, and on EF describe the semicircle E*qro*F. Produce AB to *p*, and FE to *m*, cutting A*p* in *y*. Through the centre *x* of the semicircle *EqrsF* draw *ts* perpendicular to BD, cutting the circumference of the semicircle in *s*. Draw *sp* parallel to BD. From the centre *y*, with the distance *yp*, describe the quadrant *pm*. Draw *mi* parallel to AB, cutting the semicircle described upon AB in the point *i*. In the arc B*i* take any number of intermediate points *g*, *h*, and through the points *ghi* draw *it*, *hu*, *gv*, parallel to BC. Also through the points *ghi* draw *gk*, *hl*, *im* parallel to AB, cutting FE produced in *k* and *l*. From the centre *y* describe the arcs *kn*, *lo*, cutting AB produced in *mo*. Draw *nq*, *or*, parallel to BD, cutting the lesser semicircular arc in the points *q*, *r*. Through the points *q*, *r*, *s* draw *qv*, *ru*, *st* parallel to AB; then through the points *tuv* draw the curve *tuvc*, which will be the plan of the intersection of the two cylinders. The other end of the figure exhibits the construction of the framing of carpentry, and the method in which the ribs are disposed.

2060. To describe the sides of a groin when the arches are of equal height and designed to meet in the plane of the diagonals. Let *af* and *al* (*fig.* 706.) be the axes of the two vaults, meeting each other in *a*, perpendicular to *af*. Draw AB cutting *af* in *w*, and perpendicular to *al*, draw BG cutting *al* in *b*. Make *w*A and *w*B each equal to half the width of the greatest vault, and make *b*B and *b*G each equal to half the width of the lesser vault. Draw AH and BE parallel to *af*, and draw BH and DF parallel to *al*, forming the parallelogram DEHF. Draw the diagonals HD, FE. On the base AB describe the curve B*cdef*A, according to the given height *wf* of the required form, which must serve to regulate the form of the other ribs. Through any points *cde* in the arc B*cdef*A draw the straight lines *cq*, *dr*, *es* cutting the diagonal HD at *q*, *r*, *s*. Draw *qh*, *ri*, *sh* parallel to *al* cutting the chord BG at the points *x*, *y*, *z*, *b*. Make *xh*, *yi*, *zk*, *bi* each respectively equal to *tc*, *ud*, *ve*, *wf*, and through the points G*hikl* to B, draw the curve G*hikl*B. Draw *qm*, *rn*, *so*, *ap* perpendicular to HD. Make *qm*, *rn*, *so*, *ap* respectively equal to *tc*, *ud*, *ve*, *wf*, and through the points D, *m*, *n*, *o*, *p*, H draw a curve, which will be the angle rib of the groin to stand over HD; and if the groined vault be right-angled, all the diagonals will be equal, and consequently all the diagonal ribs may be made by a single mould.

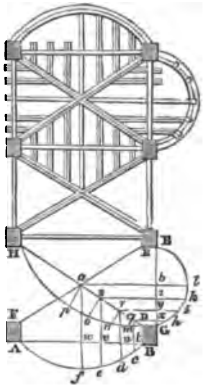


Fig. 706.

2061. The upper part of the above figure shows the method of placing the ribs in the construction of a groined ceiling for plaster. Every pair of opposite piers is spanned by a principal rib to fix the joists of the ceiling to.

2062. The preceding method is not always adopted, and another is sometimes employed in which the diagonal ribs are filled in with short ribs of the same curvature (see *fig.* 707.) as those of the arches over the piers.

2063. The manner of finding the section of an aperture of a given height cutting a given arch at right angles of a greater height than the aperture is represented in *fig.* 708.

2064. When the angle ribs for a square dome are to be found, the process is the same as for a groin formed by equal arches crossing each other at right angles, the joints for the laths being inserted as in *fig.* 707.; but the general construction for the angle ribs of a polygonal dome of any number of sides is the same as to determine the angle rib for a cove, which will afterwards be given.

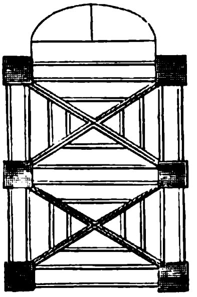


Fig. 707.

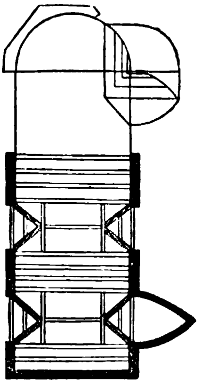


Fig 708.

2065. When a circular-headed window is above the level of a plane gallery ceiling, in a church for example, the cylindrical form of the window is continued till it intersects the plane of the ceiling. To find the form of the curb or pieces of wood employed for completing the arris, let *dp* (*fig.* 709.) be the breadth of the window in the plane of the ceiling. Bisect *dp* in *h*, and draw *h*4 perpendicular to *dp*. Make *h*4 equal to the distance the curb extends from the wall. Produce 4*h* to B. Make

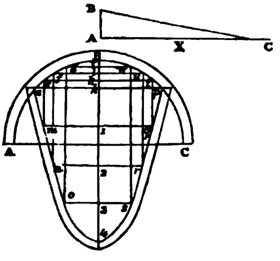


Fig. 709.

*h*B equal to the height of the window above the ceiling, and through the three points *d*, B, *p* describe the semicircle ABC for the head of the window. Divide *h*B into any number of equal parts, as 4 at the points *k*, *l*, *v*; and *h*4 into the same number of equal parts at the points 1, 2, 3. Through the points *klv* draw the lines *et*, *fu*, *gw* parallel to *dp*, and through the points 1, 2, 3 draw the lines *mg*, *nr*, *os*. Make 1*m*, 2*n*, 3*o* respectively equal to *ke*, *lf*, *vg*; as also 1*q*, 2*r*, 3*s* equal to *kt*, *lu*, *vw*; that is, equal to *ke*, *lf*, *vg*. Then through the points *dmno*4, and also through *pqrs*4, draw a curve which will form the curb required. In the section X of the figure, AC shows the ceiling line, whereof the length is equal to *h*4, and AB is the perpendicular height of the window; hence BC is the slope.

2066. The construction of a niche, which is a portion of a spherical surface, and stands on a plan formed by the segment of a circle, is simple enough; for the ribs of a niche are all of the same curvature as the plan, and fixed (*fig.* 710.) in planes passing through an axis corresponding to the centre of the sphere and perpendicular to the plane of the wall. If the plan of the niche be a semicircle (*fig.* 711.) the ribs may be disposed in vertical planes.

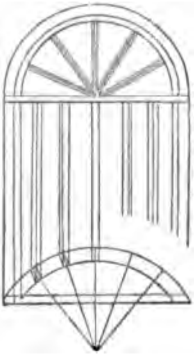


Fig. 710.

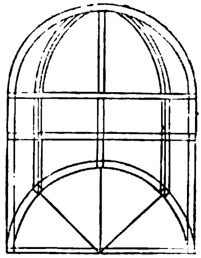


Fig. 711.

2067. In the construction of a niche where the ribs are disposed in planes perpendicular to the horizon or plan, and perpendicular to the face of the wall, if the niches be spherical all their ribs are sections of the sphere, and are portions of the circumferences of different circles. If we complete the whole circle of the plan (*fig.* 712.), and produce the plan of any rib to the opposite side of the circumference, we shall have the diameter of the circle for that rib, and, consequently, the radius to describe it.

2068. *Of forming the boards to cover domes, groins, &c.* The principles of determining the developement of the surface of any regular solid have already been given in considerable detail. In this place we have to apply them practically to carpentry. The boards may be applied either in the form of gores or in portions of conic surfaces; the latter is generally the more economical method.

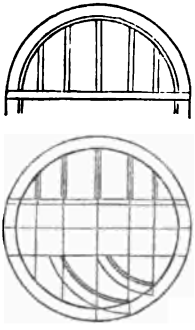


Fig. 712.

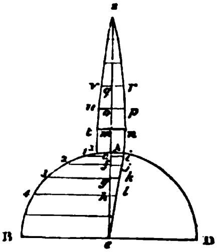


Fig. 713.

2069. *To describe a gore that shall be the form of a board for a dome circular on the plan.* Draw the plan of the dome ABD (*fig.* 713.), and its diameter BD and A*e* a radius perpendicular thereto. If the sections of the dome about to be described be semicircular, then the curve of the vertical section will coincide with that of the plan. Let us suppose the quadrant AB to be half of the vertical section, which may be conceived to be raised on the line A*e* as its base, so as to be in a vertical plane, then the arc AB will come into the surface of the dome. Make A*i* equal to half the width of a board and join *ei*. Divide the arc AB into any number of equal parts, and through the points of division draw the lines 1*i*, 2*j*, 3*k*, 4*l*, cutting A*e* in the points *efgh* and *ei* in the points *ijkl*. Produce the line *e*A to *s*, and apply the arcs A1, 12, 23, 34 to A*m*, *mo*, *oq* in the straight line A*s*. Through the points *mnoq* draw the straight lines *tn*, *up*, *vr*, and make *mn*, *op*, *qr*, as also *mt*, *ou*, *qv*, respectively equal to *ei*, *fj*, *gk*; then through the points *inpr* to *s*, and also through the points *xtuv* to *s*, draw two curves from the points *x* and *i* so as to meet each other in *s*; and the curves thus drawn will include one of the gores of the dome, which will be a mould for drawing the boards for covering the surface.

2070. In polygonal domes the curves of the gore will bound the ends of the boards; as, for example, in the hexagonal dome

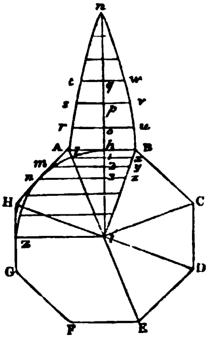


Fig. 714.

(*fig.* 714.), the plan being ABCDEFGH. Let *i* be the centre of the circle in which the hexagon may be inscribed. Draw the half diagonal *i*A, *i*B, *i*C perpendicular to any side AB of the plan. Draw the straight line *ih*, cutting AB in *h*. Let *hlm*Z be the outline of one of the ribs of the dome, which is here supposed to be the quadrant of a circle. Divide the arc *h*Z into any number of equal parts from *h* at the points *lmn*, and through these points draw *lx*, *my*, *nz*, cutting B*i* at the points *xyz*, and *ih* at the points 1, 2, 3. Extend the arcs *hl*, *lm*, *mn*, on the line *hn*, from *h* to *o*, from *c* to *p*, from *p* to *q*, and through the points *opq* draw the straight lines *ru*, *sv*, *tw* perpendicular to *hn*. Make *ou*, *pv*, *qw*, as also *or*, *ps*, *qt*, respectively equal to 1*x*, 2*y*, 3*z*; then through the points A*rst* draw a curve, and through the points *uvw* draw another curve, meeting the former one in the point *n*. Thus will be formed the gore or covering of one side of the hexagonal dome.

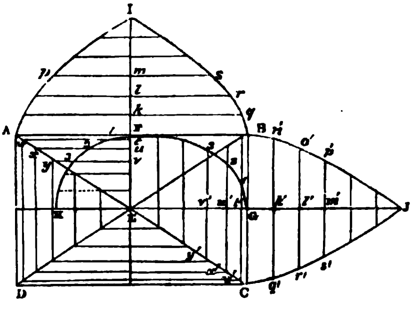


Fig. 715.

2071. When the plan of the base is a rectangle, as *fig.* 715., draw the plan ABCD and the diagonals AC and BD, cutting each other in E. Through E draw EI perpendicular to AB cutting AB in F, and through E draw EJ perpendicular to BC, cutting BC in G. Let the height of the dome be equal to half its breadth, and the section over the straight line EF a quadrant of a circle; then from the centre E describe the arc FH, its base being EF, and with the straight line EG as half the major axis of an ellipsis, and EF the minor axis, describe the quadrant GF of an ellipsis. Produce EF to I, and EG to J. Divide the arc of a quadrant FH from F into any number of equal parts, and extend the parts on the line FI to *klm*, through which draw the lines *kq*, *lr*, *ms*, &c. perpendicular to FI. Through the points 1, 2, 3, &c. draw *wt*, *xu*, *yv*, &c., cutting AE at *w*, *x*, *y*, and FE at *t*, *u*, *v*. Make *k'n'*, *l'o'*, *m'p'*, also *kq*, *lr*, *ms*, respectively equal to *tw*, *ux*, *vy*, and through the points *n'o'p'* draw a curve, also through the points *qrs* draw another curve meeting the former in I; then these two curves with the line AB will form the gore or boundary of the building of two sides of the dome. Also in the elliptical arc GF, take any number of points 1, 2, 3, and draw the lines 1*w'*, 2*x'*, 3*y'*, parallel to BC, cutting EC in the points *w'x'y'*, and GE in the points *t'*, *u'*, *v'*. Extend the arcs G1, 12, 23 from G*k'*, *k'l'*, *l'm'*, upon the straight line GJ, and through the points *k'l'm'* draw the lines *n'q'*, *o'r'*, *p's'*. Make *k'n'*, *l'o'*, *m'p'*, also *k'q'*, *l'r'*, *m's'* respectively equal to *t'w'*, *u'x'*, *v'y'*, and through the points B*n'o'p'* draw the curve BJ, and through the points C*q'r's'* draw the curve CJ; then BJC will be the gore required, to which the boards for the other two sides of the dome must be formed.

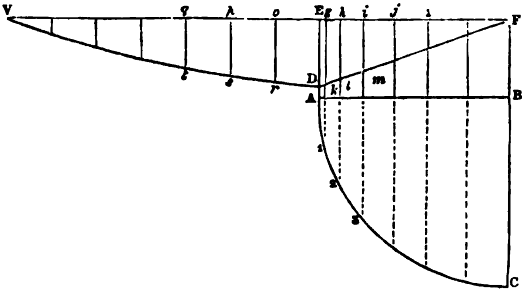


Fig. 716.

2072. A general method of describing the board or half gore of any polygonal or circular dome is shown in *fig.* 716. Let DE be half either of the breadth of a board or of one of the sides of a polygon, EF the perpendicular drawn from the centre. Draw the straight line AB parallel to EF, and draw EA and FB perpendicular to EF; then upon the base AB describe the rib AC of the vertical section of the dome. Divide the curve AC into the equidistant arcs A1, 12, 23, and through the points of division draw the lines 1*g*, 2*h*, 3*i* perpendicular to AB cutting EF at *ghi* and DF at *klm*. Produce FE to V and extend the arcs A1, 12, 23 upon the straight line EV from E successively to the points *opq*. Through the points *opq* draw the lines *or*, *ps*, *qt* parallel to ED. Make *or*, *ps*, *qt* respectively equal to *gk*, *hl*, *im*; then through the points *r s t* draw a curve, and DEV will be the half arc or half mould of the boarding.

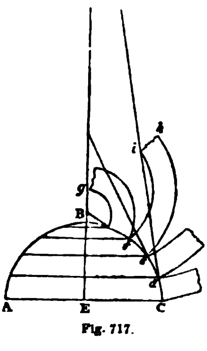


Fig. 717.

2073. *To cover a hemispherical dome by boards moulded to portions of conic surfaces.* Draw a vertical section of the dome ABC (*fig.* 717.) and divide the circumference into equal arcs *Cd*, *de*, *ef*. Through the centre E draw EB perpendicular to AC. Draw the chords *Cd*, *de*, *ef*, and produce all these chords till they meet the line EB, which they will produced in a convenient space; but those chords that are next to the bottom AC will require a distance too remote from AC; and for the present confining our attention to those cords which, when produced, would meet the line EB at a convenient distance from AC, let *ef* meet the axis EB produced in *g*, and from the point *g* as a centre with the distances *ge* and *gf* describe the arcs *eh* and *fi*. Then *efih* is the form of the board, so that its breadth is everywhere comprehended between the two concentric circles *eh* and *fi*, and when the boards are bent their edges fall on horizontal planes.

2074. We will here shortly repeat a method which has previously been given of describing an arc of a circle independent of its centre, as connected with this part of the subject, and useful in cutting out the boards of a dome where the centre is inaccessible or too distant for convenience. Let AB (*fig.* 718.) be the cord of the arc and CD its height in the middle. In this case AB will be bisected at C by the perpendicular CD. Draw the half chord AD, and perpendicular thereto draw AE, and through the point D draw EF parallel to AB; also draw AG and BH perpendicular to the chord AB cutting EF in the points G and H. Divide AC and ED each into the same number of equal parts, and draw lines through the corresponding points of division; these lines will converge, and if produced with the lines EA and FB, would all meet in one point. Divide AG into the same number of equal parts as the lines AC, ED, and from the points of division draw lines to the point D to intersect the former. A curve drawn through the points of intersection will form the arc of a circle. The other part DB is found in the same manner; and this is a convenient method, because any portion of a circle may be described within the width of a board.

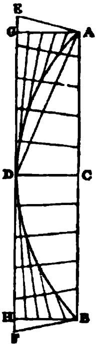


Fig. 718.

2075. To find the relation between the height and the chord of the arc. Let *abc*, &c. (*fig.* 719.) be the middle points of the boards in the arc, and from *a* draw a line parallel to the base to meet the opposite curve; also from these points draw lines to the opposite extremity of the base; then each parallel is the base, as *fa*, and the distances *eg* intersected between it, and the point where the oblique line from its extremity cuts the middle vertical is the height of the segment.

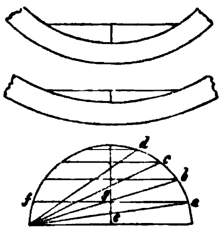


Fig. 719.

2076. It is, however, more convenient to describe the curvature of the board by a continued motion, which may be done as follows. Let AB (*fig.* 720.) be the chord of the arc. Bisect AB at C by the perpendicular CD, and make CD equal to the height of the segment. Draw DE parallel to AB, and make DE a little larger than AD; then form an instrument ADE with laths or slips of wood, and make it fast by a cross slip of wood GH. By moving the whole instrument, so that the two edges DA and DE may slide on two pins A and D, the angular point D of the instrument will describe the segment of a circle, and if the pin be taken out of A and put in the point B, the other portion DB of the segment ADB will be described in the same manner.

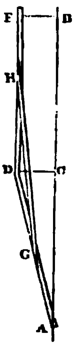


Fig. 720.

2077. The covering of an elliptical dome is formed by considering each part a portion of the surface of a cone. ABC (*fig.* 721.) is a vertical section through the greater axis of the base; the other vertical section through the axis at right angles being a semicircle; the joints of the boards therefore fall in the circumference of vertical circles.

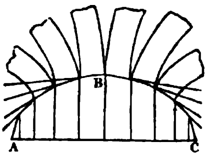


Fig. 721.

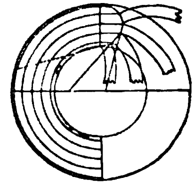


Fig. 722.

2078. In the same manner the covering of an annular vault whose section is semicircular is found, being on the same principles as now shown for a horizontal dome, which will be evident from an inspection of *fig.* 722.

BRACKETING.

2079. The pieces of wood which sustain the laths of cornices, coves, and the like, are called *brackets*, and they take in form the general outlines as nearly as possible of the forms to which they are to be finished.

2080. *A cornice bracket of any form being given, to make another similar one, or one that shall have the same proportions in all its parts.* Let ABCDEF (*fig.* 723.) be the given bracket. Draw lines from the angular points CDE, and let A*b* be the projection of the required bracket. The lines AC, AD, AE, being drawn, draw *bc* parallel to the edge BC, cutting AC in *c*; draw *cd* parallel to CD, cutting AD in *d*. Draw *de* parallel to DE, cutting AE in *e*, and draw *ef* parallel to EF, cutting AF in *f*. Then A*bcdef* is the bracket required.

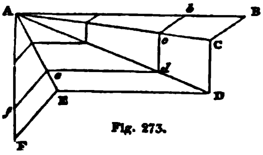


Fig. 273.

2081. *To form an angle bracket to support the plastering of a moulded cornice.* Let *fig.* 724. X be the plan of the bracket. Draw the straight line AE equal to the projection *ab* of the bracket on the plan X, and A*a* perpendicular to AE, to which make it equal. Join E*a*, and on AE describe the given form AFGHIKLE of the bracket which stands perpendicular to the line of concourse of the wall and the ceiling. From the angular points FGHIKL, draw the lines F*a*, G*b*, I*c*, H*c*, K*d*, L*d*, cutting AE in the points BCD, and *a*E in the points *a*, *b*, *c*, *d*. Draw *af*, *bg*, *ci*, *dk*, perpendicular to *a*E. Make *af*, *bg*, *ch*, *ci*, *dk*, *dl*, each respectively equal to AF, BG, CH, CI, DL, DK. Join *fg*, *gh*, *hi*, *ik*, *kl*, *l*E. Then *afghikle* is the angle bracket required.

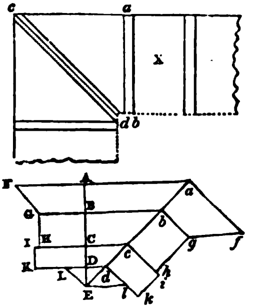


Fig. 724.

2082. An angle bracket for a cove (*fig.* 725.) may be described in exactly the same manner.

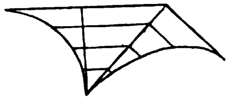


Fig. 725.

2083. When cove brackets have different projections, the method of describing the angle one is shown in *fig.* 726. Let AB, BC be the wall lines. Draw any line GD perpendicular to AB and HF perpendicular to BC. Make GD equal to the projection of the bracket from the wall represented by the line AB, and make HF equal to the projection of the bracket from the wall represented by BC. Then, as one of the brackets must be given, we shall suppose the bracket GAD described upon GD. Draw DE parallel to AB, and FE parallel to BC, and join BE. In the curve AD take any number of points Q, S, and draw QP, SR cutting GD in P, R and BE in *p*, *r*. From the points *p*, *r* draw the lines *pq*, *rs* parallel to BC, cutting HF in the points *p*, *r*. Draw *pq*, *rs* perpendicular to BE. Make *pq*, *rs* also *pq*, *rs* respectively equal to PQ, RS, &c. Ba and HC equal to GA, then through the points *aqs*, &c. draw a curve which forms the bracket for the angle. Also through the points C, *q*, *s* draw another curve, and this will form the cove bracket.

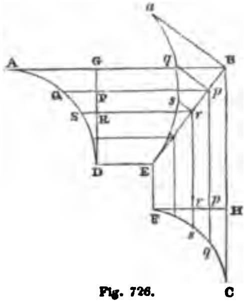


Fig. 726.

2084. The angle bracket of a cornice or cove may be formed by the method shown in X and Y (*fig.* 727.), whether the angle of the room or apartment be acute or obtuse, external or internal. Let ABC be the angle. Bisect it by the line BE. Draw GF perpendicular to BC, and make GF equal to the projection of the bracket, GC equal to its height, and FC the curve of the given bracket or rib. In the curve FC, take any number of points PQ, and parallel to BC draw the lines P*r*, Q*s*, cutting BE in the points *r*, *s*, and GF in the points R, S. Draw *rp*, *sq* perpendicular to BE, and make the ordinates *rp*, *sq* respectively equal to *rp*, *sq*, and through all the points *pq*, draw a curve, which will be the bracket as required.

2085. When the angle is a right angle, it may be drawn as at *fig.* 728., which is an ornamental bracket for the string of a stair, and traced in the same manner as that on a right-angled triangle.

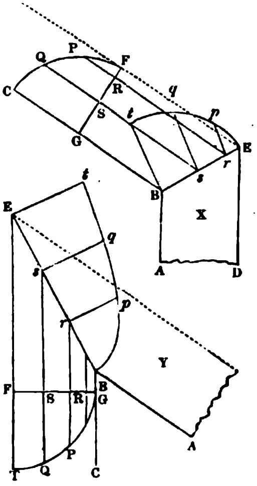


Fig. 727.

2086. In coved ceilings, the coves meeting at an angle are of different breadths, and the plan of the angle is a curve to construct the brackets. Let ABC (*fig.* 729.) represent the angle formed by the walls of the room, and let B*defg* be the plan of the bracket in the angle of a curvilinear form. Draw HM, and thereon describe the bracket HOPQ intended for that side, and in the curve HOQ take any number of points NOP, and draw the lines NR, OS, PT perpendicular to AB, cutting it in the points R, S, T. Let MQ be the height of the bracket, and draw QA perpendicular to BA, and through the points NOPQ draw the straight lines N*d*, O*e*, P*f*, cutting HM at IKLM. Draw *hm* perpendicular to BC. Make *hr*, *hs*, *ht*, *ha* respectively equal to HR, HS, HT, HA, and draw *rn*, *so*, *tp*, *aq* perpendicular to BC; also from the points *defg* draw the lines *dn*, *eo*, *fp*, *gq*, and through the points *hnopq* draw a curve, which will form the other bracket required.

2087. Whether brackets occur in external or internal angles, the method of describing them is the same, and when the brackets from the two adjacent walls have the same projection, one of them must be given to find the angle bracket. When the brackets from these walls have unequal but given projections, then the form of one of the brackets must be given in form to find the angle bracket.

2088. *To form a bracket for a moulded cornice.* On the drawing of such cornice, draw straight lines, so as to leave sufficient thickness for the lath and plaster, which should in no case be less than three-fourths of an inch. Thus the general form of the bracketing will be obtained.

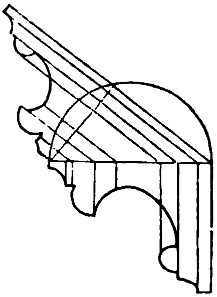


Fig. 728.

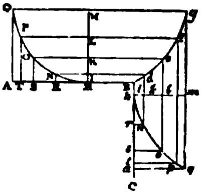


Fig. 729.

DOMES.

2089. We have, in a foregone page, mentioned a method of constructing domes with ribs in thicknesses. We here present to the reader two designs for dome-framing, wherein there is a cavity of framed work between the inner and outer domes; with moderate spans, however, simple framing is all that is required. *Fig.* 730. A is a design for a domical roof. B exhibits the method of framing the curb for it to stand upon, the section of the curb being shown upon *fig.* A. The design here given is nearly the same as that used for the dome of the Pantheon in Oxford Street, which was destroyed by fire. C is another design for a domical roof, which is narrow at the bottom part of the framing, for the purpose of gaining room within the dome.

PENDENTIVES.

2090. If a hemisphere, or other portion of a sphere, be intersected (*fig.* 731.) by cylindrical or cylindroidal arches, vaults *aa* are formed, which are called *pendentives*. The termination of these at top will be a circle, whereon may be placed a dome, or an upright drum story, which, if necessary, may be terminated by a dome.

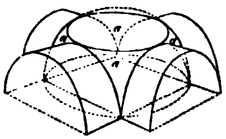


Fig. 731.

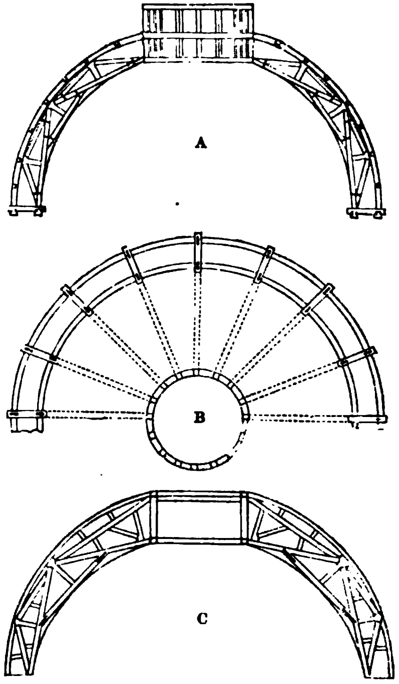


Fig. 730.

The reader will immediately perceive that many varieties may be formed. Our object here is merely to show how the carpenter is to proceed in making his *cradling*, as it is called, when pendentives are to be formed in wood.

2091. *To cove the ceiling of a square room with conical pendentives.* Let ABC (*fig.* 732.) be half the plan of the room, and DFE the half plan of the curb, at whose top the ribs are all fixed. The hyperbolical arches *agb*, *bhc* on each of the four sides are of equal height. The straight ribs *bf*, *ik*, *lm*, &c. are shown on the plan by FB, IK, LM, &c. The method of finding the hyperbolical curves *agb*, *bhc* will be explained in the following figure.

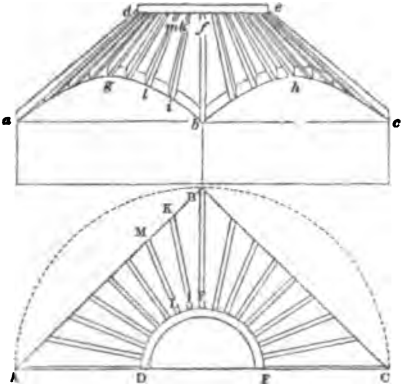


Fig. 732.

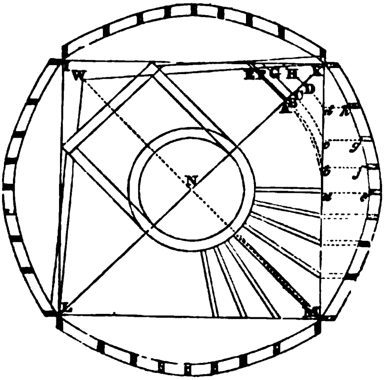


Fig. 733.

2092. *To find the springing lines of the preceding pendentives, the section in one of the vertical diagonal planes being given.* Bisect the diagonal LK (*fig.* 733.) at the point N by the perpendicular NW, which make equal to the height of the cone, and draw the sides LW and KW. Bisect the side MK of the square at *a*, and on N, with the radius N*a*, describe an arc *a*A, cutting the diagonal LK at A. Then take any points B, C, D, between A and K, and with the several radii NB, NC, ND, describe the arcs B*b*, C*c*, and D*d*, cutting KM at the points *d*, *c*, and *b*. From the points A, B, C, and D, draw AE, BF, CG, and DH perpendicular to the diagonal KL, cutting the side WK of the section of the cone at E, F, G, H. At the points *abcd* erect perpendiculars *ae*, *bf*, *cg*, and *dh* to the side ML, making each equal to their corresponding distances AE, BF, CG, and DH, which will be one half of the curve for that side from which the other may be traced. The dark parts show the feet of the ribs.

2093. *Fig.* 734. shows the method of coving a square room with spherical pendentives, which a few words will sufficiently describe. CD, DE are two sides of the plan; AFB is half the plan of the curb. In the elevation above is shown the method of fixing the ribs (which, in projection, are portions of ellipses) on two sides of the plan. *ab* is the elevation of the curb AFB; *cfd* and *dge* are ribs on each side of the plan supporting the vertical ribs that form the spherical surface, which vertical ribs support the curb *afb*. On *afb* may, if necessary, be placed a lantern or skylight; or, if light be not wanted, a flat ceiling or a dome may be placed. This pendentive is to be finished with plaster; hence the ribs must not be farther apart than about 12 inches.

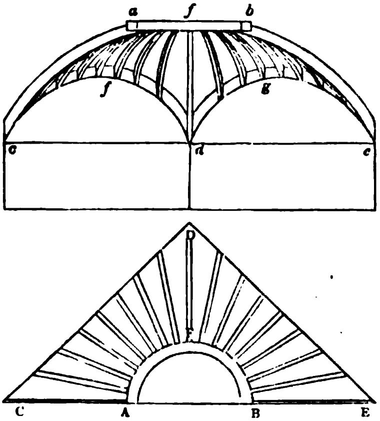


Fig. 734.

2094. For finding (*fig.* 735.) the intersection of the ribs of a spandrel dome, whose section is the segment of a circle, and whose plan is a square ABCD. Let DEFB be the section on the plane of the diagonal. First plan one quarter of the ribs, as at UC, TN, SL, RI, and QG, this last being parallel to DC or AB, the sides of the square; on V, with the radii VG, VI, VL, VN, and VC, describe the arcs GP*g*, I*ti*, L*ul*, N*vn*, &c. cutting the base DB of the angular rib in *g*, *i*, *l*, and *n*. Draw *gh*, *ik*, *lm*, and *no*, each perpendicular to DB, cutting the diagonal rib at *h*, *k*, *m*, and *o*. Then making the distances GH, IK, LM, and NO equal to the corresponding distances *gh*, *ik*, *lm*, and *no*, through the points H, K, M, O draw a curve which will be the under edge of that for the bottom of the ribs QG, RI, SL, TN, and UC, shown complete on each side of the square plan. If each of the circular segments on each side of the square plan be turned up at right angles to the plan ABCD, the ribs will then stand in their true position.

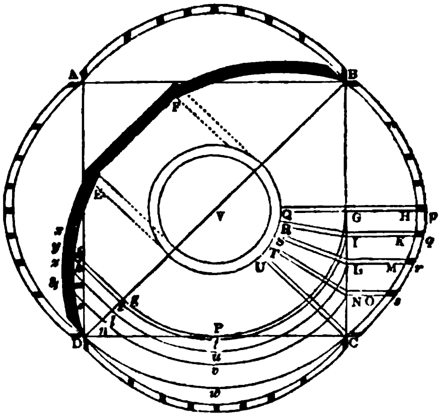


Fig. 735.

BRIDGES.

2095. We shall in this work confine ourselves to the simplest forms of timber bridges, which, as well as those of stone, will be found fully treated of in the *Encyclopædia of Engineering*, by Mr. Cresy, which forms one of the series. They mostly depend on the principle of the truss, where the span is large; and this combination of timbers we have already explained, as in stone bridges the principle of construction of the arch is the chief matter for consideration, and to that a large portion of this work has been devoted; so that, on the part of the architect, we do not resign his pretension to employment in such works, for which, indeed, as respects design, his general education fits him better than that of the engineer.

2096. The bridge over the Brenta, near Bassano, by Palladio, is an example of a wooden bridge (*fig.* 736.), which is not only elegant as a composition, but one which is economical, and might be employed with advantage where it is desirable that the piers should occupy a small space, and the river is not subject to great floods. The same great architect, in his celebrated *Treatise on Architecture*, has given several designs for timber bridges, the principles of whose construction have only been carried out further in many modern instances. He was the earliest to adopt a species of construction by which numerous piers were rendered unnecessary, and thus to avoid the consequences of the shock of heavy bodies against the piers in the time of floods. Of this sort was the bridge he threw over the rapid torrent of the Cismone (*fig.* 737.) whose span was 108 feet.

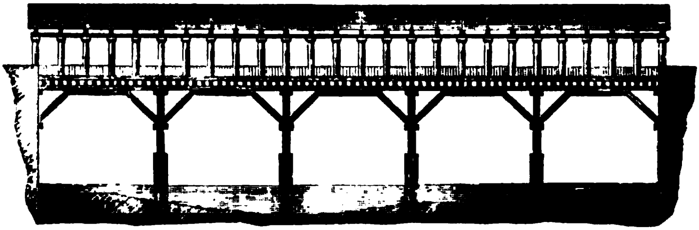


Fig. 736.

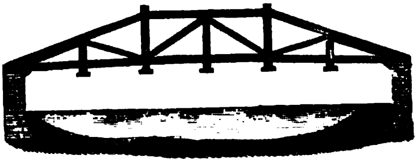


Fig. 737.

2097. Palladio has given a design for a timber bridge (*fig.* 738.) which is remarkable as having been the earliest that has come to our knowledge, wherein the arrangement is in what may be called framed voussoirs, like the arch stones of a bridge, a principle in later days carried out to a great extent, and with success, in iron as well as timber bridges.

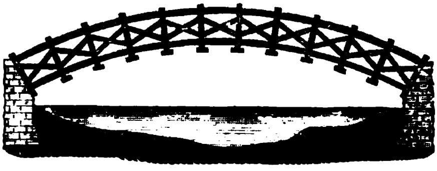


Fig. 738.

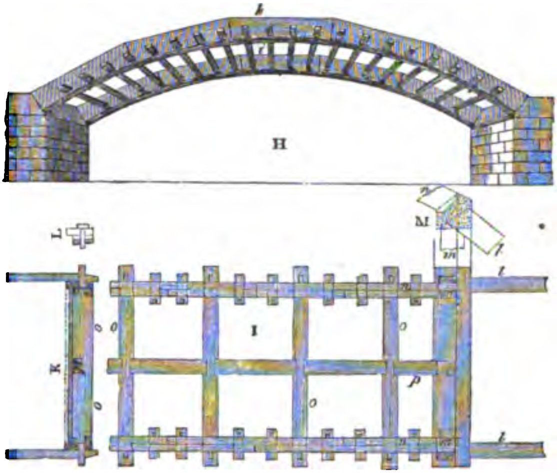


Fig. 739.

2098. We shall conclude our section on practical carpentry with a method of constructing timber bridges proposed by Price in his *Treatise on Carpentry*, and one not dissimilar in principle to the method of Philibert de Lorme, before mentioned. The bridge (*fig.* 739.) is supposed to consist of two principal ribs *ik*. The width of the place is spanned at once by an arch rising one sixth part of its extent. Its curve is divided into five parts, "which," says Price, "I purpose to be of good seasoned English oak plank, of 3 inches thick and 12 broad. Their joint or meeting tends to the centre of the arch. Within this rib is another, cut out of plank as before, of 3 inches thick and 9 broad, in such sort as to break the joints of the other. In each of these ribs are made four mortices, of 4 inches broad and 3 high, and in the middle of the said 9-inch plank (these mortices are best set out with a templet, on which the said mortices have been truly divided and adjusted). Lastly, put each principal rib up in its place, driving loose keys into some of the mortices to hold the said two thicknesses together; while other help is ready to drive in the joists, which should have a shoulder inward, and a mortice in them outward; through which keys being drove keep the whole together. On these joists lay your planks, gravel, &c.; so is your bridge compleat, and suitable to a river, &c. of 36 feet wide.

2099. "In case the river, &c. be 40 or 50 feet wide, the stuff should be larger and more particularly framed, as is shown in part of the plan enlarged, as I. These planks ought to be 4 inches thick and 16 wide; and the inner ones, that break the joints, 4 inches thick and 12 broad; in each of these are six mortices, four of which are 4 inches wide and 2 high; through these are drove keys which keep the ribs the better together; the other two mortices are 6 inches wide and 4 high; into these are framed the joists of 6 inches by 12; the tenons of these joists are morticed to receive the posts, which serve as keys, as shown in the section K, and the small keys as in L; all which inspection will explain. That of M is a method whereby to make a good butment in case the ground be not solid, and is by driving two piles perpendicularly and two sloping, the heads of both being cut off so as to be embraced by the sill or resting plate, which will appear by the pricked lines drawn from the plan I and the letters of reference." Price concludes: "All that I conceive necessary to be said further is, that the whole being performed without iron, it is therefore capable of being painted on every part, by which means the timber may be preserved; for though in some respects iron is indispensably necessary, yet, if in such cases where things are or may be often moved, the iron will rust and scale, so as that the parts will become loose in process of time, which, as I said before, if made of sound timber, will always keep tight and firm together. It may not be amiss to observe, that whereas some may imagine this arch of timber is liable to give way, when a weight comes on any particular part, and rise where there is no weight, such objectors may be satisfied that no part can yield or give way till the said six keys are broke short off at once, which no weight can possibly do."

SECT. V.

JOINERY.

2100. Joinery is that part of the science of architecture which consists in framing or *joining* together wood for the external and internal finishings of houses, such as the linings of walls and rough timbers, the putting together of doors, windows, stairs, and the like.

It requires, therefore, more accurate and nicer workmanship than carpentry, being of a decorative nature and near the eye. Hence the surfaces must be smooth and nicely wrought, and the joints must be made with great precision. The smoothing of the wood is called *planing*, and the wood used is called *stuff*, which consists of rectangular prisms roughly brought into shape by the saw, such prisms being called battens, boards, and planks, according to their breadth and thickness.

2101. We shall give but a succinct account of the joiner's tools; an acquaintance with their forms and uses being sooner learnt by mere inspection over a joiner's bench than by the most elaborate description.

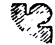
TOOLS.

2102. The first is the *bench*, whose medium height is about 2 feet 8 inches, its length about 10 or 12 feet, and its width about 2 feet 6 inches. One side is provided with a vertical board, called the *side board*, pierced with holes ranged at different heights in diagonal directions, which admit of pins for holding up the object to be planed, which is supported at the other end of it by a *screw* and *screw check*, together called the *bench screw*, acting like a *vice*. The *planes* used by the joiner are the *jack plane*, which is used for taking off the roughest and most prominent parts of the stuff, and reducing it nearly to its intended form. Its *stock*, that is, the wooden part, is about 17 inches long, 3 inches high, and 3½ inches broad. The *trying plane*, whose use is nearly the same as that last described, but used after it, the operation being performed with it by taking the shaving the whole length of the stuff, which is called *trying up*, whereas with the jack plane the workman stops at every arm's length. The *long plane*, which is used when a piece of stuff is to be tried up very straight. It is longer and broader than the trying plane, its length being 26 inches, its breadth 3⅝ inches, and depth 3½ inches. The *jointer*, which is still longer, being 2 feet 6 inches long, and is principally used for obtaining very straight edges, an operation commonly called *shooting*. With this the shaving is taken the whole length in finishing the joint or edge. The *smoothing plane*, which, as its name imports, is the last employed for giving the utmost degree of smoothness to the surface of the wood, and is chiefly used for cleaning off finished work. It is only 7½ inches long, 3 inches broad, and 2¾ inches in depth. The foregoing are technically called *bench planes*.

2103. The *compass plane* which in size and shape is similar to the smoothing plane, except that its under surface or *sole* is convex, its use being to form a concave cylindrical surface. Compass planes are therefore of various sizes as occasion may require. The *forkstaff plane* resembles the smoothing plane in size and shape, except that the sole is part of a concave cylindric surface, whose axis is parallel to the length of the plane. The form is obviously connected with its application, and, like the last named, it is of course of various sizes. The *straight block* is employed for shooting short joints and mitres, instead of the jointer, which would be unwieldy: its length is 12 inches, its breadth 3½ inches, and depth 2¾ inches.

2104. There is a species of planes called *rebate* planes, the first whereof is simply called the *rebate plune*, being, as its name imports, chiefly used for making rebates, which are receding planes formed for the reception of some other board or body, so that its edge may coincide with that side of the rebate next to the edge of the rebated piece. The length of the rebate plane is about 9½ inches, its depth about 3½ inches, and its thickness varies according to the width of the rebate to be made, say from 1¾ to ½ inch. Rebate planes vary from bench planes in having no *tote* or handle rising out of the stock, and from their having no orifice for the discharge of the shavings, which are discharged on one side or other according to the use of the plane. Of the sinking rebating planes there are two sorts, the *moving fillister* and the *sash fillister*, whereof, referring the reader to the tool itself, a sight of which he can have no difficulty in procuring, the first is for sinking the edge of the stuff next to the workman, and the other for sinking the opposite edge, whence it is manifest that these planes have their cutting edges on the under side. Without enumerating many other sorts which are in use, we shall mention merely the *plough*, a plane used for sinking a cavity in a surface not close to the edge of it, so as to leave an excavation or hollow, consisting of three straight surfaces forming two internal right angles with each other, and the two vertical sides two external right angles with the upper surface of the stuff. The channel thus cut is called a *groove*, and the operation is called *grooving* or *plowing*. This species will vary according to the width from the edge; but it is generally about 7⅝ inches long, 3⅝ inches deep.

2105. *Moulding planes* are for forming mouldings, which, of course, will vary according to the designs of the architect. They are generally about 9⅝ inches long, and 3⅜ inches deep. When mouldings are very complex, they are generally wrought by hand; but when a plane is formed for them they are said to be *stuck*, and the operation is called *sticking*.

2106. The *bead plane* is used very frequently in joinery, its use being for sticking mouldings whose section is semicircular; when the bead is stuck on the edge of a piece of stuff to form a semi-cylindric surface to the whole thickness, the edge is said to be beaded or rounded. When a bead is stuck so that it does not on the section merely fall in with its square returns, but leaves a space , thus, between the junctions at the sides, it is said to be *quirked*. The beads or planes vary from very small sizes up to the ⅜ inch and ⅞ bead. They may however be larger, and are sometimes stuck double and triple. The *snipebill plane* is one for forming the *quirk*, whereof we have spoken; but we do not think a detailed description of it necessary, more than we do of those which are made for striking *hollows* and *rounds*.

2107. The *stock and bit* is the next tool to be mentioned. Its use is for boring wood, and the iron, which varies as the size of the bore required, is made in a curve on its edge of contrary flexure so as to discharge the wood taken out. It fits into what is called the stock, which has a double curved arm working on spindles, the end opposite to the bit being pressed by the body, whose weight against the whole instrument is the power whereby the operation is performed. The bit is also called a *pin*, or *gouge bit*. It is an important tool, and much used.

2108. *Countersinks* are bits for widening the upper part of a hole in wood or iron for the head of a screw or pin, and are formed with a conical head. *Rimers* are bits for widening holes, and are of pyramidal form whose vertical angle is about 3½ degrees. The hole is first pierced by means of a drill or punch, and the rimer then cuts or scrapes off the interior surface of the hole, as it sinks downwards, by pressing on the head of the stock. According to the metal on which they are to be used they are differently formed.

2109. The *taper shell bit* is conical both within and without. Its horizontal section is a crescent, the cutting edge being the meeting of the interior and exterior conic surfaces. Its use is for widening holes in wood. Besides the above bits, there are some which are provided with a screw-driver for sinking small screws into wood with more rapidity than the unassisted hand will accomplish.

2110. The *brad awl*, the smallest boring tool, is so well known, that it would be waste of space to do more than mention it, the commonest of instruments in the science of construction.

2111. The variety of *chisels* is great. They are well known to be edge tools for cutting wood by pressure on it, or by percussion with a mallet on its handle. The *firmer chisel* is a tool used by the carpenter as well as the joiner for cutting away superfluous wood by thin chips. Those are best which are made of cast steel. If much superfluous wood is to be cut away, a strong chisel, with an iron back and steel face, is first used with the aid of the mallet, and then a slighter one with a very fine edge. The first is the *firmer* first mentioned, and the last is called a *paring chisel*, in the use whereof the force employed is from the shoulder or hand.

2112. The *mortice chisel*, whose use is for cutting out rectangular prismatic cavities in stuff is made of considerable strength. The cavity it so cuts out is called a *mortice*, and the piece which fits into it a *tenon*, whence the name of the tool. This chisel is one acted on only by the percussion of the mallet.

2113. The *gouge* is used for cutting concave forms in stuff. It is, in fact, a chisel whose iron is convex.

2114. The *drawing knife* is an oblique-ended chisel, or old knife, for drawing in the ends of tenons by making a deep incision with the sharp edge, guided by that of the tongue of a square, for which purpose a small part is cut out in the form of a triangular prism. The use of this excavation is to enter the saw and keep it close to the shoulder, and thus make the end of the rail quite smooth, for by this means the saw will not get out of its course.

2115. There are many species of the *saw*, which is a thin plate of steel, whose edge is indented with teeth for cutting by reciprocally changing the direction of its motion. The varieties are — the *ripping saw*, which is used for dividing or splitting wood in the direction of the fibres; its teeth are large, the measure being usually to the number of eight in 3 inches, such teeth standing perpendicularly to the line which ranges with the points: the length of the *plate* or *blade* of this saw is about 28 inches. The *half ripper* is used also for dividing wood in the direction of the fibres: the plate of this saw is as long as of that last described, but it has only three teeth in an inch. The *hand saw*, whose plate is 26 inches long, contains fifteen teeth in 4 inches; it is used for cross cutting, as in the direction of the fibres; for which purposes the teeth recline more than in the two former saws. The *panel saw* has about six teeth in an inch, the length of its plate being the same as the last; but in this and the hand saw thinner than in the ripping saw: it is used for cutting very thin wood, either with or across the fibres. The *tenon saw* is most used for cutting wood transverse to the fibres, as the shoulders of tenons. The plate of a tenon saw is from 14 to 19 inches long, having eight to ten teeth in an inch. This saw not being intended to cut through the whole breadth of the wood, and the plate being too thin to make a straight kerf, or to keep it from buckling, it has a thick piece of iron fixed on the edge opposite to the teeth, called the back. From the opening for the fingers through the handle of this and the foregoing saws being enclosed all round, it is called a double handle. The *sash saw* is used for forming the tenons of sashes; its plate is 11 inches in length, having about thirteen teeth to the inch. It is sometimes backed with iron, but more frequently with brass. The *dovetail saw* is used for cutting the dovetails of drawers and the like; its plate is backed with brass, it contains fifteen teeth in about one inch, and is about 9 inches long. The handles of this and the last saw are only single. The *compass saw*, for cutting wood into curved surfaces, is narrow, thicker on the cutting edge as the teeth have no set, and is without a back; the plate, near the handle, is about an inch broad, and about a quarter of an inch at the other extremity, having about five teeth to the inch; the handle is single. The *keyhole*, or *turning saw*, in its plate resembles the compass saw, but the handle is long, and perforated from end to end for inserting the plate at any distance within the handle; there is a *pad* in the lower part of the handle, through which is inserted a screw for fastening the plate therein. As its name implies, it is used for turning out quick curves, as keyholes, and is therefore frequently called a keyhole saw.

2116. The teeth of all saws, except turning and keyhole saws, are bent alternately on the contrary sides of the plate, so that all the teeth on the same side are alike bent throughout the length of the plate, for the purposes of clearing the sides of the cut made in the wood by it. The saw is a tool of great importance in every case where wood is to be divided, for by its means it can be divided into slips or scantlings with no more waste than a small slice of the wood, whose breadth is equal to the depth of the piece to be cut through, and the thickness of it equal to no more than the distance of the teeth between their extreme points on the alternate sides of the saw measured on a line perpendicular to them; whereas, by any other means, such as the axe for instance, large pieces of timber could only be reduced in size by cutting away the superfluous stuff, which would be no less a waste of labour than of the material used; and even then it would have to be reduced to a plane surface.

2117. Joiners use the *hatchet*, which is a small axe, for cutting away the superfluous wood from the edge of a piece of stuff when the part to be cut away is too small to be sawed.

2118. The *square* consists of two rectangular prismatic pieces of wood, or one of wood, and the other, which is the thinnest, of metal, fixed together, each at one of their extremities, so as to form a right angle both internally and externally; the interior right angle is therefore called the inner square, and the exterior one the outer square. Squares are, for different applications, made of different dimensions. Some are employed in trying up wood, and some for setting out work; the former is called a trying square, and the latter a setting out square. To prove a square it is only necessary to reverse the blade after having drawn a line on the surface to which it is applied: if the line of the blade on reversal do not coincide with that first drawn, the square is incorrect.

2119. The bevel consists, like the square, of a blade and handle; but the tongue is moveable on a joint, so that it may be set to any angle. When it is required to try up many pieces of stuff to a particular angle, an immoveable bevel ought to be made for the purpose; for unless very great care be taken in laying down the moveable bevel, it will be likely to shift.

2120. The *gauge* is an instrument used for drawing or marking a line on a piece of stuff to a width parallel to the edge. It consists generally of a square piece with a mortice in it, through which runs a sliding bar at right angles, called the stem, furnished with a sharp point or tooth at one extremity, projecting a little from the surface; so that when the side of the gauge next to the end which has the point is applied upon the vertical surface of the wood, with the toothed side of the stem upon the horizontal surface, and pushed and drawn alternately by the workman from and towards him, the tooth makes an incision from the surface into the wood at a parallel distance from the upper edge of the vertical side on the right hand. This line marks precisely the intersection of the plane which divides the superfluous stuff from that which is to be used. When it is required to cut a mortice in a piece of wood, the gauge has two teeth in it, and is called a *mortice gauge*, one tooth being stationary at the end of the stem, and the other moveable in a mortice between the fixed tooth and the head; so that the distances of the teeth from each other, and of each from the head, may be set at pleasure, as the thickness of the tenon may require.

2121. The *side hook* is a rectangular prismatic piece of wood, with a projecting knob at the ends of its opposite sides. The use of the side hook is to hold a board fast, its fibres being in the direction of the length of the bench, while the workman is cutting across the fibres with a saw or grooving plane, or in *traversing* the wood, which is planing it in a direction perpendicular to the fibres.

2122. The *mitre box* consists of three boards, two, called the sides, being fixed at right angles to a third, called the bottom. The bottom and top of the sides are all parallel; the sides of equal height, and cut with a saw in two directions of straight surfaces at right angles to each other and to the bottom, forming an angle of 45 degrees with the sides. The mitre box is used for cutting a piece of tried up stuff to an angle of 45 degrees with two of its surfaces; or at least to one of the arrisses, and perpendicular to the other two sides, or at least to one of them, obliquely to the fibres.

2123. The *straight edge* is a slip of wood made perfectly straight on the edge, in order to make other edges straight, or to plane the face of a board straight. It is made of different lengths, according to the required magnitude of the work. Its use is obvious, as its application will show whether there is a coincidence between the straight edge and the surface to which it is applied. When joiners wish to ascertain whether the whole surface of a piece of wood lies in the same plane, they use two slips, each straightened on one edge, with the opposite edge parallel, and both pieces of the same breadth between the parallel edges; whence each piece has two straight edges or two parallel planes. To find, therefore, whether a board is twisted, one of the slips is placed across one end and the other across the other end of the board, with one of the straight edges of each upon the surface. The joiner then looks in a longitudinal direction over the upper edges of the two slips, until his eye and the said two edges are in one plane; or otherwise the intersection of the plane passing through the eye and the upper edge of the nearest slip will intersect the upper edge of the farthest slip. If it happen as in the former case, the ends of the wood under the slips are in the same plane; but should it happen as in the latter, they are not. In the last case, the surface is said to *wind;* and when the surface is so reduced as for every two lines to be in one plane, it is said to be *out of winding*, which is the same as to say it is a perfect plane. From the use of these slips, they are denominated *winding sticks.*

2124. The *mitre square*, an instrument so called because it bisects the right angle or mitres the square, is an immoveable bevel, for the purpose of striking an angle of 45 degrees with one side or edge of a piece of stuff upon the adjoining side or edge of the said piece of stuff. It consists of a broad thin board, let or tongued into a piece on the edge called the fence or handle, which projects equally on each side of the blade, whereof one of the edges is made to contain an angle of 45 degrees with the nearest edge of the handle, or of that in which the blade is inserted. The inside of the handle is called the guide. The handle may be about an inch thick, 2 inches broad; the blade about $\frac{3}{16}$ to $\frac{1}{4}$ of an inch thick, and about 7 or 8 inches broad. As the different sorts of mouldings used in architecture will be hereafter properly defined and treated on, we shall not now stop to describe them otherwise than as immediately connected with the section under consideration. The wood used for joinery is of two sorts, white and yellow deal; the first for panelling, and the last for framing. Of late years, much American wood has been used in joinery, both for panels and frames. It works easily, is soft, free from knots, but more liable to warp than white deal.

2125. The *arris* of a piece of stuff is the edge formed by two planes.

MOULDINGS.

2126. When the edge of a piece of wood is reduced to a cylindrical form, it is said to be *rounded*, which is the simplest kind of moulded work. (*Fig.* 740.) When a portion of the arris is made semicylindrical, so that the surface of the cylindrical part is flush both with the face and edge of the wood, with a groove or sinking made in the face only, the cylindrical part is called a bead, and the sinking a quirk; the whole combination (*fig.* 741.) being called a *quirked bead.*

2127. If a quirk is also formed on the other or returning face, so as to make the rounded part at the angle three fourths of a cylinder, the moulding (see *fig.* 742.) is called a *bead and double quirk.*

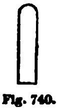


Fig. 740.

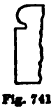


Fig. 741.

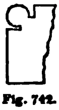


Fig. 742.

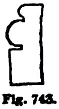


Fig. 743.

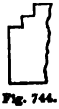


Fig. 744.

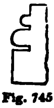
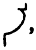


Fig. 745.

2128. If two semicylindrical mouldings both rise from a plane parallel to the face, and one comes close to the edge of the piece and the other has a quirk on the further side, and its surface flush with the face of the wood, as in *fig.* 743., the combination is called a *double bead* or *double bead and quirk*, wherein the bead next to the edge of the stuff is much smaller than the other.

2129. Mouldings are usually separated from one another, and often terminated by two narrow planes at right angles (*fig.* 744.) to each other: these are called *fillets*, and show two sides of a rectangular prism. The different pieces of the combination of mouldings are called *members.* A semicylindrical moulding, rising from a plane parallel to the face, and terminated on the edge by a fillet (*fig.* 745.), is called a *torus.* In the figure there are two hemicylindrical mouldings, whence that is called a *double torus.* The reader must observe that the distinction between torus mouldings and beads in joinery is, that the outer edge of the former always terminates with a fillet, whether the torus be single or double;

whereas a bead never has a fillet on the outer edge. A repetition of equal semicylindrical mouldings, springing from a plane or cylindrical surface, is called *reeds*. In joinery, the , *cima recta*, and , *cima reversa*, are called respectively the *ogee* and *ogee reverse*. The ovolo , so named from its egg-like form, and the *quarter round*, the fourth part of a cylindrical surface, are the remaining of the principal mouldings used in joinery. When the margin of any framing terminates on the edges next to the panel, with one or more mouldings, which both advance before and retire from the face of the framing to the panelling, the mouldings thus introduced are called *bolection mouldings*.

DOORS.

2130. We shall now more particularly address ourselves to the subject of doors and their mouldings. A door, properly made, is formed by framing and fitting pieces of stuff together of the same thickness; those which are horizontal (*fig.* 746.) AAAA being called *rails*, and those which are vertical BBBB being called *styles*. These form a skeleton into which *panels*, usually of a less thickness, are fitted. And this, indeed, is the general practice in all systems of framed joinery. In doors, the upper rails are called *top rails*; the next in descending, *frize rails*; the next, which are usually wider than the two first, are called the *lock* or *middle rails*; and the lowest, from their situation, are called *bottom rails*. The styles on the flanks are called *outside styles*, and those in the middle are called *middle styles*. The panels are also named from their situations on the door; thus CC, being the uppermost, are called *frize panels*; the next DD are called *middle panels*, and EE *bottom panels*. The rails and styles are wedged together, being previously morticed and tenoned into each other. The student should, however, to obtain a clear comprehension of the method adopted, see a door put together at the bench. The varieties and forms of doors are dependent upon the will of the architect, from whom the design of the whole emanates; it will be, therefore, here sufficient to mention the three sorts, viz. the *common door*, just described; the *jib door*, which is made with the same finishings and appearance as the room in which it is placed, so as not to have the appearance of a door; and, lastly, *folding doors*, which open from the centre of the doorway, and are used for making a wider communication between two apartments than a common door will permit, or, in other words, to lay two rooms into one.

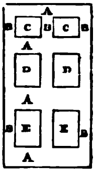


Fig. 746.

2131. Though the panelling of framed work is generally sunk within the face of the framing, it is for outside work sometimes made flush. In the best flush work, the panels are surrounded with a bead formed on the edge of the framing, and the work is called *bead and flush*. In the commoner kind of flush framing, the bead is run only on the two edges of the panel in the direction of the fibres, and is called *bead and butt*.

2132. The different denominations of framed doors, according to their mouldings and panels and framed work in general, are as follows. The figures by which they are represented are sections of doors through one of the styles, wherein only a small part of the panel is shown, or they may be equally considered as vertical sections, through the top rail and part of the panel below it.

2133. *Fig.* 747. represents the commonest door. It is without mouldings, and the panel is a straight surface on both sides. It is technically described, first mentioning the number of panels intended in it, as a *door square and flat panel on both sides*. We shall not, in the following, repeat the observation as to the number of panels, that being always supposed as mentioned.

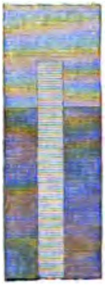


Fig. 747.

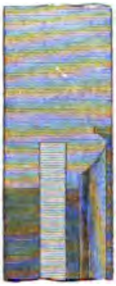


Fig. 748.

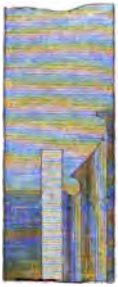


Fig. 749.

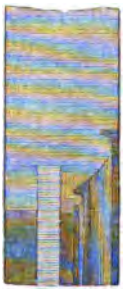


Fig. 750.

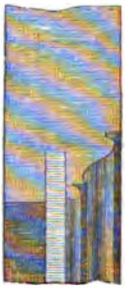


Fig. 751.

2134. *Fig.* 748. represents the rail and panel of a door, with a quirked ovolo and a fillet on one side, but having no mouldings on the other. The panel flat on both sides, it is described as a *door with quirked ovolo, fillet and flat with square back.*

2135. *Fig.* 749. only differs from the last in having a bead instead of a fillet, and is described as *quirked ovolo, bead and flat panel with square back.*

2136. *Fig.* 750., with an additional fillet on the framing, is described as *quirked ovolo, bead fillet and flat panel with square back.* The back, in the foregoing and following cases, is described as square, because of its having no mouldings on the framing, and of the panel being a straight surface on one side of the door.

2137. In *fig.* 751. the framing is formed with a quirked ogee, and a quirked bead on one side and square on the other, the surface of the panel being straight on both sides, and the door is described as *quirked ogee, quirked bead and flat panel with square back.*

2138. *Fig.* 752. only differs from the last in the bead being raised above the lower part of the ogee and a fillet. It is described as *quirked ogee, cocked bead and flat panel with square back.*

2139. *Fig.* 753. is described as a door with *cove, cocked bead, flat panel and square back.*

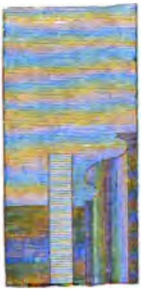


Fig. 752.

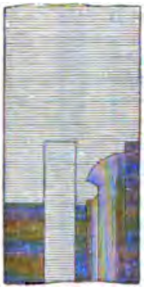


Fig. 753.

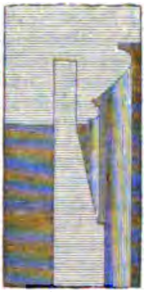


Fig. 754.

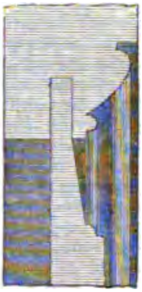


Fig. 755.

2140. *Fig.* 754. is a combination, by which much strength is imparted to the door, and it is therefore much used for external doors. It is, however, often in the interior of houses, and is described, *quirked ovolo, bead fillet and raised panel on front and square back.* It is from the raising of the panel that the additional strength is acquired.

2141. *Fig.* 755. resembles the last in general appearance, the difference being in the ovolo on the raised panel. It is described, *quirked ovolo, bead and raised panel, with ovolo on the raised panel and square back.* When an external door has raised panels, they are always placed towards the exterior.

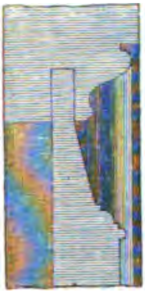


Fig. 756

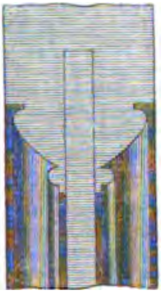


Fig. 757.

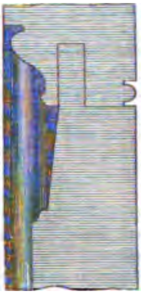


Fig. 758.

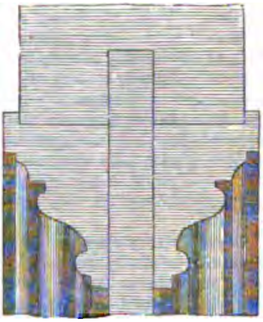


Fig. 759.

2142. In *fig.* 756. there are more mouldings than in the last on the raised panel. It is described, *quirked ogee, raised panel with ovolo and fillet on the rising and astragal on the flat of panel in front and square back.*

2143. *Fig.* 757. is described, *quirked ovolo, bead fillet and flat panel on both sides.* This description of doors is used where a handsome appearance is to be equally preserved on both sides of the door, as between rooms, or between halls or principal passages and rooms.

2144. *Fig.* 758. is a combination used, as all bead butt and bead flush work is, where strength is required. The form here given is described, *bead and flush front and quirked ogee, raised panel with ovolo on the rising, grooved on flat panel on back.*

2145. The series of mouldings are, as we have before mentioned, called *bolection* mouldings (*fig.* 759.), and are laid in after the door is framed square and put together. They project beyond the framing on each side. When bradded on through the sides of the quirks, the heads of the brads will be entirely concealed; but it is to be observed that, in driving the brads, they must not be directed towards the panels, but into the solid of the framing. The form of these bolection mouldings is of course varied according to the pleasure of the architect.

SHUTTERS.

2146. *Shutters*, which are the doors of window openings, are framed upon the same principles as doors themselves; but their backs are very often flush. In the better sort of buildings they are folded into recesses called *boxings*, whereof we shall give a figure below as an example of the ordinary method; but as the extent and different forms of windows vary, the ingenuity of the architect will be often required to contrive his shutters within a very small space. Into minutiæ we cannot enter in a work of this nature; however, in all their shapes, they are dependent on the leading principles given.

2147. *Fig*. 760. is a plan of the shutters, architrave, sash-frame, and part of the sash of common shutters. The cavity which forms the *boxing* into which the sashes fold is formed by the ground B (upon which the architrave A is nailed), the *back lining* F of the boxing, and the *inside lining* G of the sash frame, whereof H is the *inside bead*. L is the *outside lining* of the sash-frame, M the *back lining* of it, and K the *parting bead*, so called from parting the upper and lower sash. The vacant space between the pulley piece I and M, is a cavity which contains the weights for balancing the sashes, N shows the plan of the sash. The shutters, when stretched out in their different folds, are supposed to cover one half of the window, another series being supposed to be placed on the other side of it. The *front shutter* CCC is hung by hinges at *a* to the inside lining G of the sash-frame. The inner shutters DDD and EE are called the *back flaps*, the former whereof is hinged on to the front shutter at *b*, and the latter is hinged on to DDD at *c*. It will be immediately seen that these will thus altogether turn upon the hinges at *a*, and cover, in one straight line, from both sides, the whole of the light of the window; it being contrived that each boxing shall contain as many shutters as will cover one half, that is, from the centre of the hinge to the centre of the window. When the boxes are scanty, the hinge may be placed as shown in X attached to the figure.

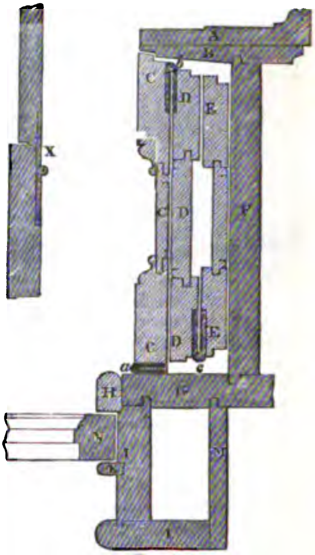


Fig. 760.

2148. It would be impossible to place before the reader the infinite variety of examples required for the application of shutters to windows; in ordinary cases, the example we have given will sufficiently exhibit the method to be adopted. On occasions wherein it is not applicable, the architect must apply himself to the work *pro re natâ*, in which, with very little attention, he will not find insurmountable difficulty.

HINGEING.

2149. A very essential consideration in the neatness and beauty of joiners' work, is the formation of the joints on which are placed the hinges of doors and shutters. They ought to be so continued as to preserve the uniformity of the door or shutter on both sides, and as much as possible to be close enough to exclude a rush of air between the edges of the bodies to be hinged together, which, in this cold climate, is essential. In these joints, both angles of one of the bodies is usually beaded, to conceal the open space, which would otherwise be seen; and for preserving the appearance of the work, the hinges are made of such a curvature towards the eye, as to seem, when painted, a part of the bead itself on that side where the knuckle is placed, so that when hung the whole may appear to be one bead.

2150. The section of a door style, and part of the *hanging style* at the joint, are represented in A and B (*fig*. 761.), wherein the centre of the bead on each side is in the line of the straight part of the joint from the opposite side. In this figure, C is the centre of the bead, AG part of the joint in a line with its edge. Joining AC, draw AB perpendicular thereto. The other part BH is perpendicular to EF, which

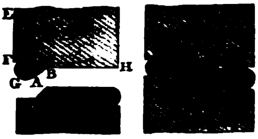


Fig. 761.

is the face of the door or hanging style. This is a joint suitable for many purposes, and may be made with common hinges. If crooked, it will assist in excluding the current of air, a point of no mean importance in this climate.

2151. In *fig.* 762. A and B exhibit a plane joint, beaded similarly on both sides. In this case, the plane of the joint is a tangent to the cylindrical surfaces of the two beads; and as the margin on each side is alike, no check to the rush of cold air is afforded. The hinge, moreover, is such that it cannot be made in the usual manner, but must be formed as at C.

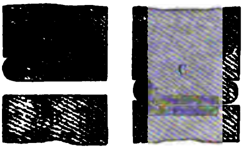


Fig. 762.

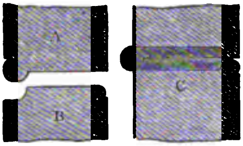


Fig. 763.

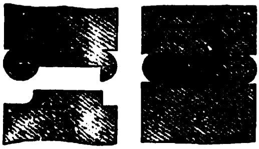


Fig. 764.

2152. *Fig.* 763. A and B represent a hinging wherein the plane of the joint from one side is directed to the axis of the bead on the other. The principle in it is the same as that in *fig.* 761., and it may therefore be hinged with common hinges, as shown in C, in which the two parts are conjoined. The methods shown in this and *fig.* 761. are useful in cases wherein a part of the margin is concealed on one side of the door.

2153. *Fig.* 764. A and B exhibit the beads of similar size on each side, and exactly opposite to each other, the joint being broken by indenting a part terminated by a plane directed to the axis of the two opposite beads. The hinges are required merely of the common form, the arrangement is strong, and the apartment rendered comfortable by their use. In C the parts are shown as hinged together.

2154. In *fig.* 765. the beads are on both sides, but not on the same piece, as in the last figure. The appearance is uniform, but the bead, which projects the whole of its thickness, is weakened. The junction is seen in the representation at C.

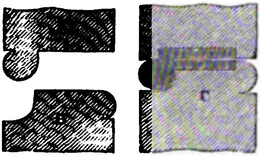


Fig. 765.

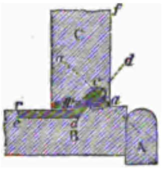


Fig. 766.

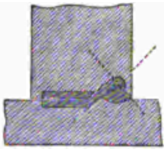


Fig. 767.

2155. *Fig.* 766. is a method that has been adopted for concealing the hinges of shutters. A is the inner bead of the sash-frame, B the inside lining, C the style of the shutter. For the form of the joint, let *af* be the face of the shutter, perpendicular to *ar* the face of the inside lining. Let the angle *f*, *a*, *r* be bisected by the straight line *aa*, and in the centre take *c*. Draw *dd* perpendicular to *aa*, cutting it in *c*, which is the centre of the hinge. From *c*, as a centre, describe the arc *am*, which must be hollowed out from the inside lining of the sash through the height of the shutter. In order to make room for the opening and shutting of the hinge, the internal right angle of the shutter must be cut out of its edge to the breadth of the hinges. The *toils* of the hinge are here for the purpose of strengthening them, represented of different lengths.

2156. In *fig.* 767. the hinges, which are for a door, are concealed, as the door allows it in the thickness of the wood, the ends of the hinges being of equal lengths.

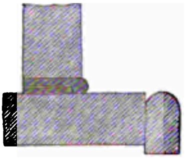


Fig. 768.

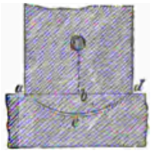


Fig. 769.

2157. *Fig.* 768. shows the common method of hingeing shutters, a mode wherein the whole thickness of the hinge is let into the thickness of the shutter, the inside lining being assumed as too thin to afford sufficient hold for the screws employed to fasten them.

2158. *Fig.* 769. exhibits the hanging of a door with the centres concealed. Let *ad* be the side of the jamb in contact with the edge of the door; bisect it in *b*, and draw *bc* perpendicular to *ad*, make *bc* equal to *ba* or *bd*, and join *ac* and *cd*; from *c*, as a centre, describe the arc *aed*, which will show the portion to be hollowed out of the jamb. The centres are fixed to the upper and under parts of the door, and the former is to be so constructed as to allow its being taken out of the socket to unhang the door when required.

2159. Shutters are usually hung in the way represented in *fig.* 770., wherein the centre

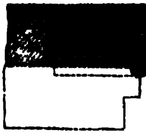


Fig. 770.

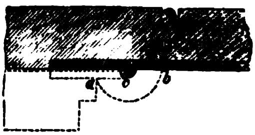


Fig. 771.

of the knuckle of the hinge is exactly opposite to the perpendicular part of the rebate. The dotted lines exhibit the flap when folded back.

2160. When the axis of the knuckle cannot be disposed so as to fall opposite to the joint, the hinge is to be placed as shown in *fig.* 771. Thus, *ab* being the distance of the edge of the flap from that of the shutter, bisect it in *c*, which will be the point opposite whereto the centre of the hinge is to be placed. This arrangement is necessary, both when the shutters are not square at the ends, and when the boxing is restricted in space; the principle being to place the centre of the knuckle of the hinge at half the distance of the edge of the flap from the rebate on the edge of the shutter. In *fig.* 772. the two parts are shown hinged together.

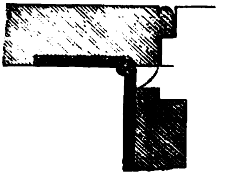


Fig. 772.

2161. When a door has attached to it any projection, and, when open, it is requisite to bring it parallel to its place when shut, the knuckle of the hinge (*fig.* 773.) must project at least as far as the projection in question. An inspection of the diagram, wherein the dotted lines show the situation of the door when folded back, will sufficiently convey the mode of conducting this expedient.

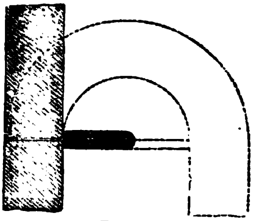


Fig. 773.

2162. *Fig.* 774. is the representation of what is called a *rule joint*, which is used when the piece to be hung is not required to open to more than a right angle. In this case, the centre of the hinge is necessarily in the centre of the arc. In *fig.* 775. the expedient shows the method turned to a right angle.

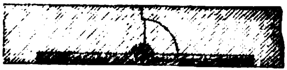


Fig. 774.

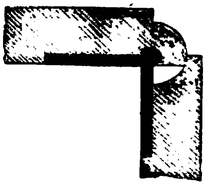


Fig. 775.

2163. The various methods of hingeing to suit every possible case would occupy a very large space, were we to enter into them; and even after exhausting all the cases that we may have imagined, others would arise to which no example given might be applicable; we therefore leave this portion of the subject of joinery, under an impression that the principles have been sufficiently developed to enable the student to pursue from them the application to any case that he may be called upon to put in practice.

SASH-FRAMES AND SASHES.

2164. In *fig.* 760. the connection between the shutters and sash-frame has been fully explained; we may now, therefore, proceed to the detail of a common sash-frame with its sashes, supposing them to be hung so as to be balanced by weights, suspended by sash-lines running over pulleys, capable of balancing those of the sashes themselves. On the case of *French sashes*, which open like doors, we do not think it necessary to dilate. *They* are, in fact, nothing more than glazed doors; and the principal object for attainment in their construction, is to prevent the rain from penetrating into the apartments they serve, as well where they meet in the middle as at their sills, which is a subject requiring much care and attention.

2165. In *fig.* 776. is shown the construction of a sash-frame, and the method of putting together the several parts, wherein R is the elevation of the frame, of which ABCD is the outer edge. The thinner lines at EF, GH, FG, are grooves whose distances from the edges of the sash-frame LM and KI are equal to the depth of the boxing, together with three-eighths of an inch more that is allowed for margin between the face of the shutter, when, in the boxing, and the edges ML and KI of the sash-frame next to the bead. S is a horizontal section of the sides, whereon is shown also the plan of the sill. T is a vertical section of the sill and top, in which is shown the elevation of the pully style *m* and *n*; and the pullies let into the pully piece. U is the horizontal section of the sides, showing also a plan of the head of the sash-frame. V the elevation of the outer side of the sash-frame; the outside lining being removed for the purpose of showing the work within the sash-frame. In this *fg* is the *parting strip* fastened by a pin; *ed* one of the weights connected to the sash by means of a line going over the pulley *c*, the other end being fixed to the edge of the sash.

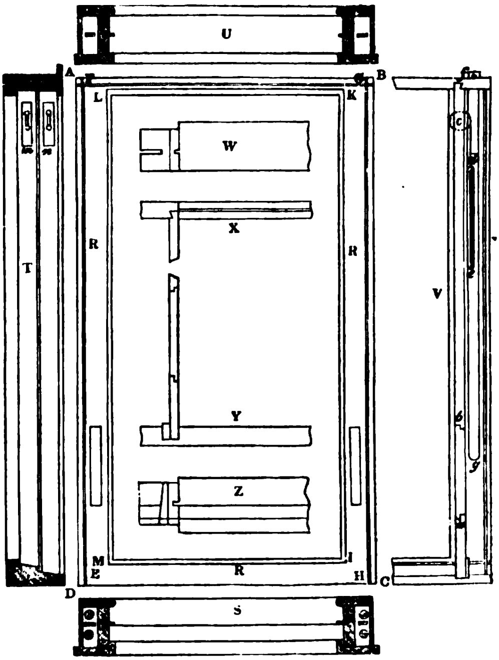


FIG. 776.

The weight *de* is made equal to one half the weight of the sash. W is the head of the sash-frame before put together, and X shows the edge of W. Y is the edge of the bottom, exhibiting the manner of putting the styles in it, and Z is the plan of Y. *Fig.* 777., Nos. 1. and 2., are sections of the sills of sash-frames, with sections of the under rail of the sash, showing the best method of constructing them, in order to prevent rain from driving under the sash-rail. In each of these, A is the section of the bottom rail, B a section of the bead tongued into the sill, C a section of the sill. *Fig.* 778. exhibits sections of the meeting rails of the upper and lower sashes, with side elevations of the upright bars; C is the rebate for the glass, D a square, E and F an astragal and hollow moulding, G a fillet. The smaller letters mark the same parts of the under sash. *Fig.* 779. is the section of an upright bar with the plans of two horizontal bars, showing the *ranking* or manner in which they are put together to keep the upright bars as strong as possible. The thickness of the tenon in general is about one sixteenth of an inch to the edge of the hollow of the astragal, and close to the rebate on the other side. *hh* is a dowel to keep the horizontal bars still firmer together. In this diagram the letters refer to the same parts as in the preceding figure; and it is also to be observed, that no rebate is made for the glass on the inside meeting rail, a groove being made to answer that purpose. *Fig.* 780. exhibits four sections of sash bars. But their forms, as in the case of mouldings, generally depends on the taste of the architect.

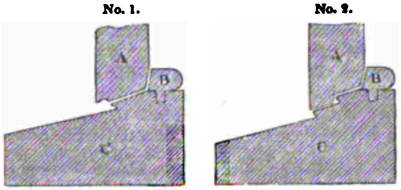

No. 1. No. 2.

FIG. 777.

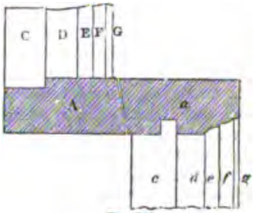


FIG. 778.

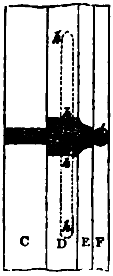


FIG. 779.

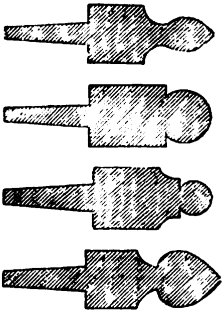


FIG. 780.

GROUNDS.

2166. Grounds are pieces of wood framed together, and attached to walls, around windows, doors, or other openings in buildings, for the facility of fixing architraves or other mouldings upon them; in all these cases they ought to be fixed vertical on the face and edge, and the workman should take especial care to fix them firm and solid in every part; for, without accuracy and firmness, the inside work cannot be well finished to them, as it is to be recollected that in plastered rooms the plaster is worked to them.

2167. In fixing window grounds, the sash-frame must be first carefully placed so as to stand perfectly vertical; and then the face of the ground must stand quite parallel to the face of the sash-frame, and project about three quarters of an inch from the face of the naked brickwork, so as to leave a sufficient space for the thickness of the plaster. The edge of the ground should be in the same plane with the edge of the sash-frame, or, as the workmen term it, "out of winding." The edge of the architrave, when finished, in ordinary cases, will stand about three eighths of an inch within the inner edge of the sash-frame, so that a perpendicular line down to the middle of the grounds would stand exactly opposite to a perpendicular line down to the middle of the sash-frame.

FLOORS.

2168. In the laying of floors, the first care to be taken is that they be perfectly level, which, owing to the nature of the materials whereof they are constructed, is a difficult task. The chief sorts of floors may be divided into those which are *folded*, that is, when the boards are laid in divisions, whose side vertical joints are not continuous, but in bays of three, four, five, or more boards in a bay or fold; and those which are *straight joint*, in which the side joints of the boards are continuous throughout their direction.

As soon as the windows are fixed, the floors of a building may be laid. The boards are to be placed on their best face, and put to season till the sap is quite exhausted, when they may be planed smooth, and their edges shot and squared. The opposite edges are brought to a breadth by drawing a line on the face parallel to the other edge with a flooring guage, after which the common guage is used to bring them to a thickness, and they are rebated down on the back to the lines drawn by the guage.

2169. The next operation is, to try the joints, which, if not level, must be brought so, either by *furring up* if they be hollow, or by adzing down if they are convex, the former being more generally the case.

2170. The boards used for flooring are battens, or deals of greater breadth, whose qualities are of three sorts. The best is that free from knots, shakes, sapwood, or cross-grained stuff, selected so as to match well with one another. The second best is free of shakes and sapwood, and in it only small sound knots are permitted. The third, or most common sort, are such as are left after taking away the best and second best.

2171. The joints of flooring-boards are either quite square, ploughed and tongued, rebated, or dowelled; and in fixing them they are nailed on one or both edges, when the joints are plain and square without dowels. When they are dowelled, they may be nailed on one or both sides; but in the best dowelled work the outer edge only is nailed, by driving the brad through the edge of the board obliquely, without piercing its surface, which, when the work is cleaned off, appears without blemish.

2172. In laying the floor-boards, they are sometimes laid one after the other, or one is first laid, then the fourth, at an interval of something less than the united breadth of the second and third together. The two intermediate boards are then laid in their places with one edge on the edge of the first board and the other upon that of the fourth board, the two middle edges resting against each other, rising to a ridge at the joint. In order to force these boards into their places, two or three workmen jump upon the ridge till they have brought the under sides of the boards close to the joints; they are then fixed in their places with brads. This method is that first mentioned under this head, and in it the boards are said to be folded. We have here mentioned only two boards, but four boards are most commonly folded at a time, and the mode is always resorted to when a suspicion exists that the boards are not sufficiently seasoned, or they are known not to be so. The headings of these folds are either square, splayed, or ploughed and tongued. If a heading occurs in the length of the floor, it should be invariably made to fall over a joist, and one heading should not meet another.

2173. In dowelled floors the dowels should be placed over the middle of the interjoint rather than over the joists, so that the edge of one board may be prevented from passing that of the other. When the boards are only bradded upon one edge, the brads are concealed by driving them in a slanting direction through the outer edge of every successive board, with piercing the upper surface. In adzing the under sides of floor-boards opposite each joist, great care should be taken to clip away the stuff straight, and also to avoid taking away more of the stuff than is necessary, in which case the soundness of the floor will not be compromised.

FRAMING.

2174. In *fig.* 781. are shown several methods for framing angles in dadoes, skirtings, troughs, and other objects, whereof A exhibits the method of mitring dado on exterior angles in an apartment. In fixing this together, brads may be driven from each side. B is a method of framing used for troughs or other rectangular wooden vessels. C is a method of putting dado or skirting together at any interior angle of a room. This mode is also employed for water-trunks, or troughs. In D is shown the manner of fixing and finishing two pieces of framing together, with a bead at their meeting, by which the joint is concealed. It is used only in common finishings. In those of a better sort the angle is kept entire, and only a three-eighth bead used at the joint, the angle being kept entire. It is a great point in all joiner's work to preserve the sharpness of the angles of the work, and many prefer the method shown in F, without any bead at the joint. In this the joint is made as close as possible, and is well glued together. If additional strength be required, blockings may be glued in the interior angle, which will make it quite firm. The method, by a simple mitre at E is not so good as at A, because it has no abutment.

2175. When it is required to glue up large work, those edges which are to receive the glue should be well warmed at a fire, and then, while warm, and the glue as hot as possible, they should be united, inasmuch as glue never holds well when it is chilled or cold.

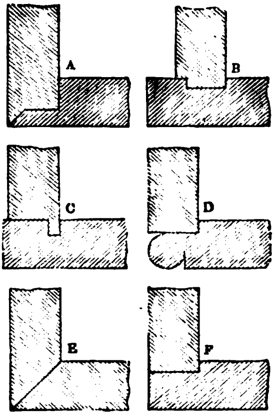


Fig. 781.

STAIRS.

2176. Stairs and their handrails are among the most important objects of the joiner's skill. The choice of situation, the design, and what suits the general convenience of the building, sufficiency of light, and easy ascent, are indeed matters for the exercise of the architect's talent; but all these, however well contrived and arranged, are incomplete without a clear and accurate execution of the work.

2177. There are some leading principles which are common to all staircases, of whatsoever materials they may be constructed. Thus it is a maxim that a broad step should be of less height than one which is narrower; and the reason is sufficiently obvious, because in striding, what a man loses in breadth he can more easily apply in raising himself by his feet. Now, as in common practice it is found that the convenient rise of a step 12 inches in width is $5\frac{1}{2}$ inches, it may be assumed as some guide for the regulation of other dimensions. Thus $12 \times 5\frac{1}{2} = 66$, which would be a constant numerator for the proportion. Suppose, for instance, a step 10 inches in breadth, then $\frac{66}{10} = 6\frac{3}{5}$ inches would be the height; and this agrees very nearly with the common practice. The breadth of steps in the commonest staircase may be taken at 10 inches at a medium. In the best staircases the breadth of the step should not be less than 12 inches, neither should it be more than 18 inches.

2178. Having adjusted the proportions of the steps, our next consideration is to ascertain the number of risers which will be necessary to carry us from one floor to another. Suppose, for example, the height from the top of one floor to that of the next be 15 ft. = 180 in.; here, if the steps are each of 6 inches rise, we have $\frac{180}{6} = 30$, which is the number of risers necessary to ascend from floor to floor. If the height divided by the rise of each step should not give an exact number of risers, it is better to add one rather than diminish the number. Thus, suppose the distance from floor to floor to be 13 ft. 2 in. = 158 in., then $\frac{158}{7} = 22\frac{4}{7}$. Here it would be better to take 23 risers, for the steps must be equal in height.

2179. The width of the better sorts of staircases should not be less than 4 feet, to allow of two persons freely passing each other; but the want of space in town houses often obliges the architect to submit to less in what is called the *going* of the stair.

2180. The parts of every step in a staircase are one parallel to the horizon, which is called the *tread* of the step, terminated on the edge by a moulded or rounded *nosing*, and the other perpendicular to the horizon, which is called the *riser* of the step.

2181. It is not our intention to detail more than will be necessary for comprehending the work of the joiner in its application to stairs, which have many varieties of structure, dependent on the character, situation, and destination of the building. To this end we shall now, therefore, describe the method of carrying up *dog-legged*, *bracket*, and *geometrical stairs*.

2182. A DOG-LEGGED STAIRCASE is one which has no opening or well-hole, and in which the rail and balusters of the progressive and returning flights fall in the same vertical planes. The steps in it are fixed to strings, newel, and carriages, the ends of the steps of the inferior kind terminating only upon the side of the string without any housing. Y and Z in *fig.* 782. are the plan and elevation of a staircase of this kind; AB is the lower newel whereof the part BC is turned. On the plan, *a* is the seat of this newel. DE and FG in Y are the lower and upper string boards framed into newels, KL is a joist framed into the trimmer I. The lines on the plan represent the faces of the steps in the elevation without the nosings. MO and FQ are called the upper and lower ramps, the method of drawing which is as follows: — In the upper ramp, for example, produce the top of the rail HM to P; draw MN vertical, and produce the straight part ON of the pitch of the rail to meet it in N, making NO equal to NM. Draw OP at a right angle to ON. From P, as a centre, describe the arc MO, and then the other concentric circle, which will complete the ramp required. The *story rod* RS is in the fixing of all staircases a necessary instrument; for in fixing the steps and other work by a common measuring rule, bit by bit, the chances are that an excess or defect will occur, to make the staircase faulty; which cannot be the case if the story rod is applied to every riser, and such riser be regulated thereby.

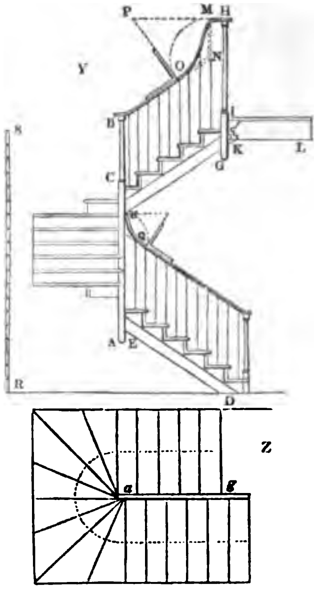


Fig. 782.

2183. A Bracket Staircase is one which has an opening or well, with strings and newels, and is supported by landings and carriages. The *brackets* are mitred to the end of each riser, and fixed to the string board, which is usually moulded like an architrave. In this sort of staircase the same methods are to be observed in respect of dimensions and laying off the plan and section as in a dog-legged staircase. Nothing is to be done without the story rod just described, which must be constantly applied in making and setting up the stairs. The method of forming the ramps and knees has been touched upon in the preceding article, and the few particulars we intend to give respecting scrolls and handrailing will be reserved for a subsequent page. In bracket stairs the internal angle of the steps is open to the end, and not closed by the string, as in common dog-legged stairs; the neatness also of the workmanship is as much attended to as in geometrical stairs. The balusters should be nicely dovetailed into the ends of the steps by twos, and the face of each front baluster is to be in a plane with the front face of the riser, and all the balusters being equally divided, the face of the middle one must of course stand in the middle of the face of the riser of the preceding step. The treads and risers are previously all glued up and blocked together, and when put in their places the under side of the step is nailed or screwed into the under edge of the riser, and then rough bracketed to the strings, as in a dog-legged staircase, in which the pitching pieces and rough strings are similar.

2184. A Geometrical Staircase is one whose opening is down its centre, or, as it is called, an open newel, in which each step is supported by one end being fixed in the wall or partition, the other end of every step in the ascent having an auxiliary support from that immediately below it, beginning from the lowest one, which, of course, rests on the floor. The steps of a geometrical staircase should, when fixed, have a light and clean appearance, and, for strength's sake, the treads and risers, when placed in position, should not be less than 1½ inch thick, supposing the going of the stair or length of the step to be 4 feet. For every 6 inches in length of the step an eighth of an inch should be added. The risers should be dovetailed into the cover, and in putting up the steps, the treads are screwed up from below to the under edges of the risers. The holes for sinking the heads of the screws ought to be bored with a centre bit and fitted closely in with wood well matched, so that the screws may be entirely concealed, and appear as a uniform surface without blemish. Brackets are mitred to the risers, and the nosings are continued round; but this practice induces an apparent defect, from the brackets, instead of giving support, being themselves unsupported, and actually depending on the steps, being indeed of no other use than merely tying together the risers and treads of the internal angles of the steps; and from the internal angles being hollow, except at the ends, which terminate by the wall at one extremity, and by the bracket at the other, there is an appearance of incomplete finish. The cavetto or hollow is carried all round the front of the slip, returned at the end, and again at the end of the bracket, thence along the inside of it, and then along the internal angle at the back of the riser.

2185. The ancient mode, however, was the best, in which the wooden was an imitation of the method of constructing geometrical stairs in stone, which will be found under Masonry, in the previous Section III.; that is to say, the making of the steps themselves solid, and in section of the form of a bracket throughout their length. This is a more expensive method, but it is a solid and good one, and is still practised on the Continent, especially in France.

2186. In *fig.* 783. X is the plan and Y the elevation, or rather section, of a geometrical staircase. AB in X is what is called the *cur-tail step* (curved like the tail of a cur dog), which must be the first step fixed. CCC are the *flyers* supported from below by rough carriages, and partly from the string board DHEF in Y. The ends next the wall are sometimes housed into a notch board, and the steps then are made of thick wood and no carriages used. GGG are *winders* fixed to bearers and pitching pieces, when carriages are used to support the flyers. The winders are sometimes made of strong stuff firmly wedged into the wall, the steps screwed together, and the other ends of the steps fixed to the string DEHF. In all cases of wooden geometrical stairs their strength may be greatly augmented by a flat bar of wrought iron coinciding with the under side and screwed to the string immediately below the steps. HIK in Y is the wall line of the sofite of the winding part of the stairs, and LMN part of the rail supported by two balusters upon every step. Where the space of the going of the stairs is confined, the French have long since introduced, as in *fig.* 784., the practice of placing the balusters outside the steps, which affords more room for persons ascending and descending.

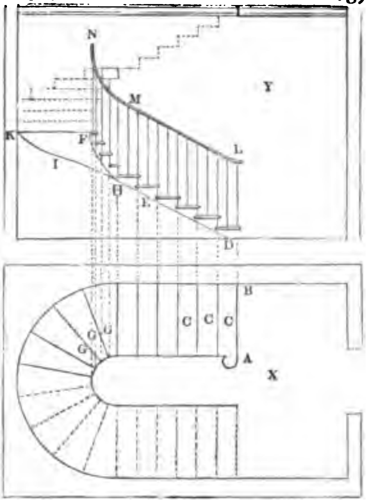


Fig. 783.

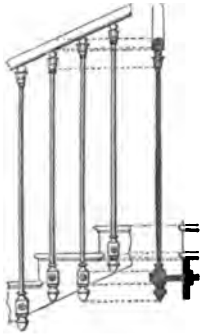


Fig. 784.

HANDRAILS AND CUR-TAIL STEP.

2187. The upper part of the fence formed by capping the balusters of stairs is called the *handrail*, whose use, as its name imports, is for a support to the hand in the ascent and descent of stairs. The hand, for support to the body, should glide easily over it without any strain, whence it is evident, that to be properly formed, it must necessarily follow the general line of the steps, and be quite smooth and free from inequalities. It must be obvious to the reader who has thus far followed us throughout the different previous portions of our labours, that the chief principle of handrailing will be dependent on the methods of finding sections of cylinders, cylindroids, or prisms, according to three given points in or out of the surface, or, in other words, the section made by a plane through three given points in space. The cylinder, cylindroid, and prism are hollow, and of the same thickness as the breadth of the rail, or the horizontal dimension of its section; and their bases, their planes or projections on the floor. Thus is formed the handrail of a staircase of a portion of a cylinder, cylindroid, or prism whose base is the plane of the stair, for over this the handrail must stand, and is therefore contained between the vertical surface of the cylinder, cylindroid, or prism. As the handrail is prepared in portions each whereof stands over a quadrant of the circle, ellipse, or prism of the base which forms the plane, such a portion may be supposed to be contained between two parallel planes, so that the portion of the handrail may be thus supposed to be contained between the cylindrical, cylindroidal, or prismatic surfaces and the two parallel planes. The parts to be joined together for forming the rail must be so prepared that in their place all the sections made by a vertical plane passing through the imaginary solid may be rectangular: this is denominated *squaring the rail*, and is all that can be done by geometrical rules. But handrails not being usually made of these portions of hollow cylinders or cylindroids, but of plank or thicknesses of wood, our attention is naturally drawn to the consideration of the mode in which portions of them may be formed from planks of sufficient thickness. The faces of the planks being planes, they may be supposed to be contained between two parallel planes, that is, the two faces of the plank. Such figures, therefore, are to be drawn on the sides of the plank as to leave the surfaces formed between the opposite figures, portions of the cylindrical, cylindroidal, or other surfaces required, when the superfluous parts are cut away. A mould made in the form of these figures, which is no more than a section of them, is called the *face mould*.

2188. The vertical, cylindrical, or cylindroidal surfaces being adjusted, the upper and lower surfaces must be next formed; and this is accomplished by bending another mould round the cylindrical or cylindroidal surfaces, generally to the convex side, and drawing lines on the surface round the edge of such mould. The superfluous wood is then cut away from top to bottom, so that if the piece were set in its place, and a straight edge applied on the surfaces so formed, and parallel to the horizon directed to the axis of the well-hole, it would coincide with the surface. The mould so applied on the convex side for forming the top and bottom of the piece, is called the *falling mould*. For the purpose of finding these moulds it is necessary to lay down the plan of the steps and rail; next, the falling mould, which is regulated by the heights of the steps; and lastly, the face mould, which is regulated by the falling mould, and furnishes the three heights alluded to.

2189. *Fig.* 785. exhibits two of the most usual forms of handrails. A is that most commonly employed, that marked B is called a *toad's back rail*.

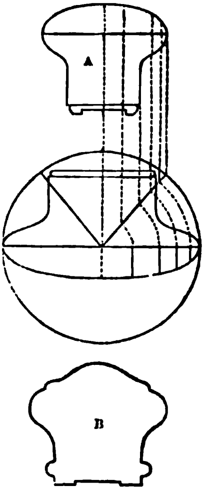


Fig. 785.

2190. *Fig.* 786. shows the method of drawing the scroll for terminating the handrail at the bottom of a geometrical staircase. Let AB be the given breadth; draw AE perpendicular to AB, which divide into eleven equal parts, and make AE equal to one of them. Join BE, bisect AB in C and BE in F. Make CD equal to CF and draw DG perpendicular to AB. From F, with the radius FE or FB, describe an arc cutting DG at G. Draw GH perpendicular to BE cutting BE at O. Draw the diagonals DOK and IOL perpendicular to DOK. Draw IK parallel to BA; KL parallel to ID, and so on to meet the diagonals. From D as a centre, with the distance DB, describe the arc BG. From I as a centre, with the distance IG, describe the arc GE. From K as a centre, with the distance KE, describe the arc EH. From L as a centre, with the distance LH, describe the arc HP. Proceed in the same manner and complete the remaining three quarters, which will finish the outside of the scroll. Make BR equal to the breadth of the rail; namely, about two inches and a quarter. Then with the centre D and distance DR describe the arc RS, with the centre I and distance IS describe the arc ST, and with the centre T and distance KT describe the arc TU, and the scroll will be completed.

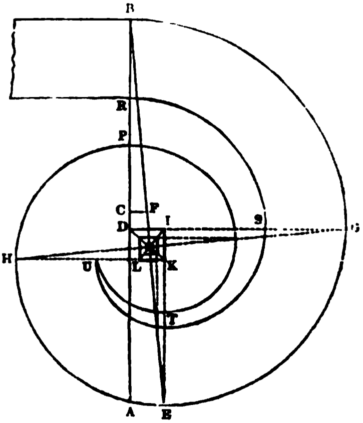


Fig. 786.

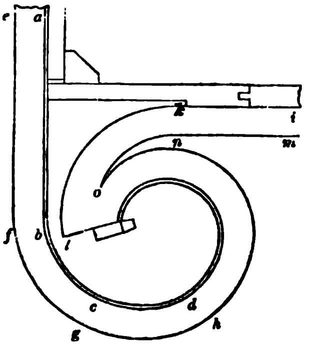


Fig. 787.

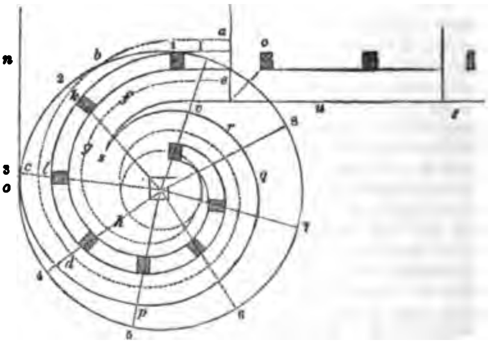


Fig. 788.

2191. *Fig.* 787. gives the construction of the cur-tail step, or that which lies under the scroll, *abcd* is the veneer that covers the riser; *efgh*, the nosing of the cover or horizontal part of the step; *ikl* the face of the string board, and *mno* the projection of the nosing.

2192. In *fig.* 788. is shown the cover board for the cur-tail step, *abcd* and *efgh* in dotted lines represent the plan of the scroll; *opqrs*, the nosing of the curtail step; *t*, *u*, *v*, *s*, the nosings and ends of the risers. The circle 1, 2, 3, &c. is described from the centre of the scroll, and divided into equal parts equal to the distances of the balusters from centre to centre, and lines are drawn to the centre of the scroll in order to ascertain the middle of the balusters, by giving a regular gradation to the spaces. The whole of the spiral lines in this and the previous figure are drawn from the same centres as the scroll.

FORMATION OF BODIES BY JOINING THEM WITH GLUE.

2193. The way in which bodies are glued up together for different purposes will be given below, and with them will close this section.

2194. *Fig.* 789. shows at A a section of two boards glued up edge to edge. At B the face of the same is seen. C shows the section of two boards glued edge to edge, each piece being grooved, and a *tongue* inserted at their junction. By similar means a board may be increased to any width, be the pieces whereof it is composed ever so narrow. D shows two boards fixed at right angles, the edge of one being glued on the side of the other. A block for the purpose of strengthening the joint is fitted and glued to the interior side.

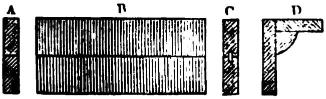


Fig. 789

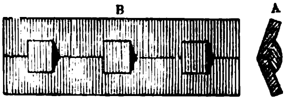


Fig. 790.

2195. *Fig.* 790. A is a section of two boards to be joined at an oblique angle. They are mitred and glued together with a block at the angle. B shows the inner sides of the boards so fixed. It is by repeating this operation that columns are glued up.

2196. *Fig.* 791. A is the section of an architrave. The moulding is usually, if not always, glued to the board; the vertical line therefore, showing the extreme boundary of the moulded part, is the section of the piece to be glued, B is the face of the architrave, C and D a section and front of it before it is moulded, E a section of it with the button and nail to show the way in which the two parts are glued together, and F shows the back of the architrave with the buttons which are used for the purpose of bringing the two surfaces to be glued together in contact, till after they are set and fully held together, being knocked off when the glue has become hard, and then the moulding shown at A and B is stuck.

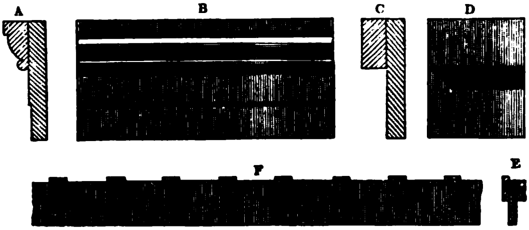


Fig. 791.

2197. *Fig.* 792. exhibits the method of gluing up a solid niche in wood where A is the elevation. The work is performed in the same way as if it were stone or brick, except that the joints are all parallel to the plane of the base, because of the difficulty of making a joint with curved surfaces, which would necessarily be the case if they all tended to the centre of the sphere. B and C are the two bottom courses, where the vertical joints are made to break, as seen in the elevation A.

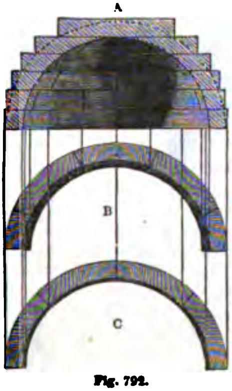


Fig. 792.

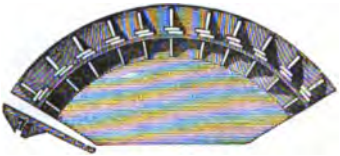


Fig. 793.

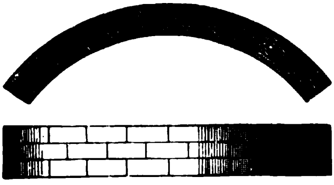


Fig. 794.

2198. In *fig.* 793. is exhibited the mode in which veneers are glued together for the purpose of forming cylindrical surfaces. Brackets with their faces upwards are nailed to a board. Their ends are perpendicular, and a cavity is left between them sufficient to receive the veneers and wedges. In A the thin part in the form of an arc shows the veneers as in the state of glueing, the wedges being on the convex side. B is a section of the board and bracket. The work when putting together should be dry and warm, and the glue should be hot. When this last has set hard, the wedges must be slackened, and the veneers, which now form a solid, taken out.

2199. *Fig.* 794. is a strong method of forming a concave surface by laying the veneer upon a cylinder, and backing it with blocks in the form of bricks, which are glued to the convex side of the veneers and to each other. The fibres of the blocks are to be as nearly as possible parallel to the fibres of the veneers. A is the section of the cylinder veneer and blocks, and B shows the convex side of the blocks.

2200. *Fig.* 795. is another mode of glueing veneers together with cross pieces screwed to a cylinder, the veneers being placed between the former and the latter.

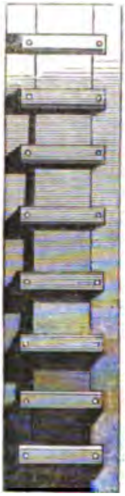


Fig. 795.

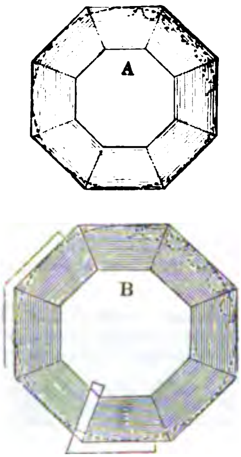


Fig. 796.

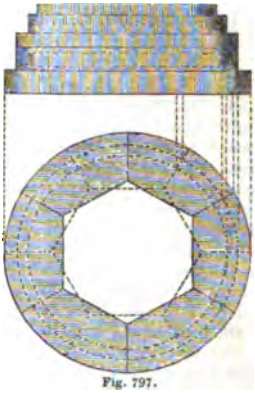


Fig. 797.

2201. In *fig.* 796. is shown the method of glueing up columns in pieces, which here are eight in number, each being glued to the other after the manner of *fig.* 790. The workman should be careful to keep the joints out of the flutes, when the columns are to be fluted, by which the substance will be more likely to prevent the joints giving way. A is a section of the column at top, and B at the bottom. After glueing together, the octagons and mitres should be correctly laid down for the true formation of the joints. In B are shown two bevels, one for trying the mitres, and the other for trying the work when put together.

2202. *Fig.* 797. is the mode of glueing up the base of a column. It is formed in three courses, the pieces in each of which are made to break joint over one another. The horizontal joints of the courses must be so adjusted as to fall at the junction of two mouldings, forming a re-entering angle. After the glue is set quite hard, the rough base is sent to the turner, by whom it is reduced into the required profile. The fibres of the wood should lie horizontally, in which direction the work

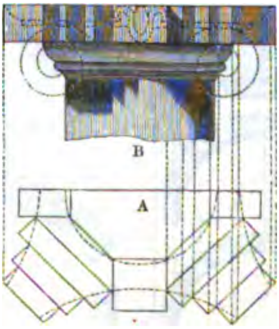


Fig. 798.

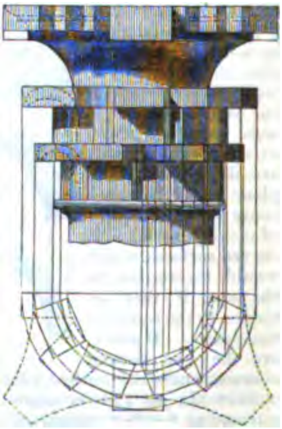


Fig. 799

will stand much better than when they are vertical. A is the plan of the base inverted, and B is the elevation.

2203. The formation of a modern Ionic capital is given in *fig.* 798., wherein A is the plan inverted, showing the method of placing the blocks; and B is the elevation.

2204. *Fig.* 799. is the method of glueing up for the leaves of the Corinthian capital, A is the plan inverted, and B is the elevation. The abacus is glued up in the same manner as in the preceding example.

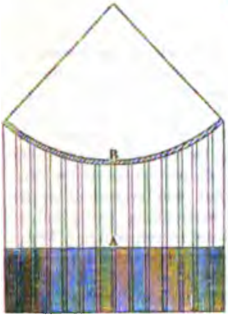


Fig. 800.

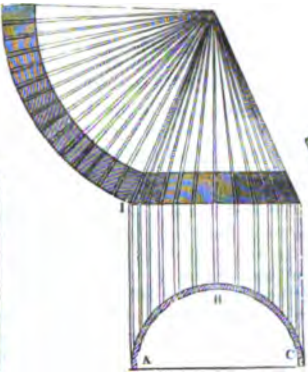


Fig. 801.

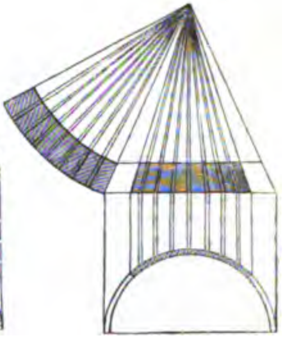


Fig. 802.

2205. *Fig.* 800. exhibits the mode of forming a cylindrical surface without veneers, by means of equidistant parallel grooves, A is the elevation, and B the plan.

2206. *Fig.* 801. exhibits the method of covering a conic body. It is, in fact, no more than covering the frustum of a cone, and is accomplished by two concentric arcs terminated at the ends by the radii. The radius of the one arc is the whole slant side of the cone, that of the other is the slant side of the part cut off. In this case, the grooves are directed to the centre, and filled in with slips of wood glued as before. The plan is shown by the circle ABC. The arc HI must be equal to the circumference ABC.

2207. *Fig.* 802. shows the same thing for a smaller segment.

2208. *Fig.* 803. shows the manner of glueing up a globe or sphere by the same method. A is the face of the piece; B the edge showing the depth of the grooves; C shows the mould for forming the piece to the true curvature; and D the faces of two pieces put together.

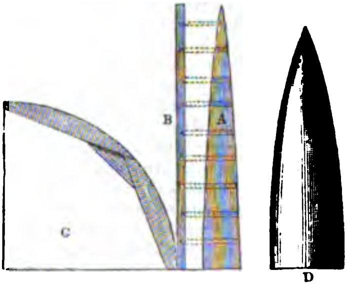


Fig. 803.

Sect. VI.

SLATING.

2209. An account of the materials used by the slater have been detailed in Chap. II. Sect. VIII., and will not leave us much to say on their application.

2210. The tools used by this artificer are the *scantle*, which is a guage by which slates are regulated to their proper length; the *trowel;* the *hammer;* the *zax*, an instrument for cutting the slates; a small *handpick*, and a *hod and board* for mortar.

2211. Slating is laid in inclined courses, beginning from the eaves and working upwards, the courses nearest the ridge of the roof being less in width than those below. The *lap* of one slate over another is called its *bond*, and it is the distance between the nail of the under slate and the lower end of the upper slate. The *bed* of a slate is its under side, and the upper side is called its *back*. The part of each course which is exposed to the weather is called its margin. The slates are nailed to close or open boarding lying on the back of the rafters with nails, which should be of copper or zinc. If iron nails are used they should be well painted. The operation of cutting or paring the side and bottom edges of the slates is called *trimming* them; but the head of the slate is never cut. In that part holes are pierced through the slates by which the nails pass to the boarding. The operations of the slater are of so simple a nature, that we do not further think it necessary to detain the reader on this section, which with that of Sect. VIII. Chap. II. in this Book affords all the information that can be required.

Sect. VII.

PLUMBERY.

2212. The plumber has but few working tools, for the facility with which the metal in which he works is wrought does not render a variety necessary. The principal are — a heavy iron *hammer*, with a short but thick handle. Two or three different sized *wooden mallets*, and a *dressing and flatting tool*, which is made of beech wood, usually about 18 inches long and 2¼ inches square, planed smooth on one side, and rounded on the other or upper side. It is tapered and rounded at one of its ends for convenient grasping by the workman. Its use is to stretch and flatten the sheet lead, and dress it into the shape required for the various purposes whereto it is to be applied, by the use of its flat and round sides as wanted. The *jack and trying planes*, similar to those used by carpenters, for planing straight the edges of their sheet lead when a regular and correct line is requisite. They also use a line and roller called a *chalk line*, for lining out the lead into different widths. Their cutting tools are *chisels* and *gouges*, of different sizes, and *cutting knives*. The latter are for cutting the sheet lead into strips and pieces to the division marked by the chalk line. They use also *files* of different sizes for making cistern heads to pipes, for pumpwork, &c. For the purpose of soldering, they have a variety of different sized *grozing irons*, which are commonly about 12 inches long, tapered at both ends, the handle end being turned quite round to allow of its being held firmly in the hand whilst in use. The opposite end is spherical, or more usually spindle-shaped, and proportioned to the different situations for which they are required. The grozing iron is heated to redness when in use. The *iron ladles* are of three or four sizes, and used for the purpose of melting lead or solder. The plumber's *measuring rule* is 2 feet long, in three parts, each of 8 inches. Two of the legs are of box-wood, and the third of steel, which is attached to one of the box legs by a pivot whereon it turns, and shuts into the other legs in a groove. The steel leg is useful for passing into places which the plumber has to examine, into which anything thicker would not easily enter, and it is often used also for removing oxide or other extraneous matter from the surface of the heated metal. The plumber moreover is provided with *centre bits* of all sizes, and a stock to work them in, for perforating lead or wood where pipes are to be inserted, as well as with compasses, for striking out circular portions of lead. *Scales and weights* are also in constant requisition, as nothing done by the plumber is chargeable till the lead is weighed.

2213. The method most commonly adopted in laying sheet lead for terraces or flats, is to place it on a surface as even as possible, either of boarding or plastering. If boards are employed, they should be sufficiently thick to prevent warping or twisting, which, if it occur soon, causes the lead to crack or to become unsightly. As sheets of lead are not more than about 6 feet in width, when the area to be covered with them is large, joints become necessary, which are contrived in various ways to prevent the wet from penetrating. To do this, the best method is that of forming *rolls*, which are pieces of wood about 2 inches square extending in the direction of the joint, planed and rounded on their upper side. These being fastened under the joints of the lead between the edges of the two sheets which meet together, one is dressed up over the roll on the inside, and the other over both of them on the outside, whereby all entry of the water is prevented. No fastening is required other than the adherence of the lead by close hammering together and down on the flat: indeed, any fastening would be injurious, as by it the lead would not have free play in its expansion and contraction from heat and cold. If rolls are not employed, which from their projection are in some cases found inconvenient, *seams* are substituted for them; but they are by no means equal to the roll either for neatness or security. They are formed by merely bending up the two edges of the lead, and then over one another, and then dressing them down close to the flat thoughout their length. Though some solder the joints, it is a bad practice, and no good plumber will do it, for the same reason as that just given in respect of fastenings in flats. A leaden flat, as well as a gutter, should be laid with a fall to keep it dry. A quarter of an inch in a foot is sufficient inclination for lead, if the sheets be 20 feet long, so that in this case they will be 5 inches at one end higher than at the other. This *giving a current*, as it is called, is usually provided for by the carpenter previous to laying the lead.

2214. Round the extreme edges of flats and gutters where lead is used, are fixed pieces of milled lead which are called *flashings*. When the lead work is bounded by a wall of brick or stone work, the flashings are passed on one edge into and between a joint of the work, and the edges of the flat or gutter being bent up, the other edge of the flashing is dressed over it. If there be no joint into which the flashing can be inserted, it is fastened on that side with wall hooks. *Drips* in flats and gutters are used when the length of the gutter or flat is greater than the length of the sheet of lead, or sometimes for convenience, or to avoid joining lead by soldering it. They are formed by raising one part above another, and dressing the lead round, as has been described for rolls.

2215. The pipes used for the purposes of building are proportioned to their uses. Those, for instance, for carrying away the soil from a water closet, or the conveyance of water from roofs and sinks, are of course of larger diameter than those called *service pipes*, which are merely, as their name implies, for laying on water.

TABLE OF THE WEIGHT OF LEADEN PIPES.

Pipes of ¾-inch bore	weigh per yard	10 lbs.
Pipes of 1-inch bore	—	12 lbs.
Pipes of 1¼-inch bore	—	16 lbs.
Pipes of 1½-inch bore	—	18 lbs.
Pipes of 1¾-inch bore	—	21 lbs.
Pipes of 2-inch bore	—	24 lbs.

2216. The work of the plumber is estimated by its weight and the time employed in fixing it. The weights and thicknesses of different sizes of sheet lead have been already given in Chap. II. Sect. VI. of this Book.

2217. The lead generally used in roofing and guttering is from 7 to 12 lbs. to the superficial foot, and great vigilance on the part of the architect is required, in these days of contracts, to see that his employer has the thickness, or, which is the same thing, the weight that has been contracted for.

2218. We do not think it necessary to describe at length the machinery of a water closet. Every one knows that the principle on which it is formed is that of a head of water in a cistern placed above it, which by means of a lever attached to a valve in the cistern allows a body of water to rush down and wash the basin, whose valve is opened for the discharge of the soil at the same moment that the water is let down from the cistern. Various instruments for this purpose have been contrived and patented, but we are not aware of any better than those which were made by the late Mr. Bramah, almost as soon as the subject formed a matter of inquiry. The reader will obtain by the inspection of one a far better notion than words or diagrams will convey.

2219. As it is a branch of the plumber's trade to find and fix the pumps for the supply of water to a dwelling, we think it right to furnish a description of the three sorts commonly used, which are the *lifting*, the *common*, and the *force pump*.

2220. *Fig.* 804. is a diagram of a lifting pump, in which ABCD is a short cylinder submerged in the well or other reservoir, whence the water is to be raised. In this cylinder a valve is placed at *x*, above which the pipe or tube CE is carried upwards as high as is requisite for the delivery of the water. In the cylinder AD a water-tight piston moves vertically, being worked by rod or framework as seen in the diagram. To this piston is fixed a valve at *v* opening upwards. On the descent of the piston the pressure against the water opens the valve *v*, and the cylinder between the two valves is filled with the water. When the piston is then raised, the water between the valves being pressed upwards against the valve *x*, opens it, and is driven into the tube CE, from which, on the renewed descent of the piston, its return is intercepted by the valve *x*. The water follows the piston in its ascent by the hydrostatic pressure of the water in the reservoir outside the cylinder; and on the next descent of the piston the water will again pass through the valve *v*, and will be driven through the valve *x* on its next ascent. It is manifest from inspection that the valve *x* relieves the valve *v* from the pressure of the column of water in the tube CE during the descent of the piston; for if the valve *v* were subject to that pressure during the descent of the piston, it could not be opened by the pressure of the water in the well, inasmuch as its level is necessarily below the level of the water in the pipe CE. The valve *v* prevents the return of the water through the piston during its ascent. In raising the piston a force is required sufficient to support the entire column of water from the valve *v* to the surface of the water in the tube CE. To estimate this, we must take the weight of a column of water whose base is equal to the area of a section of the piston,

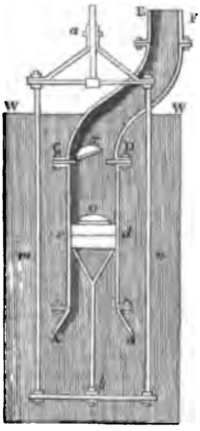


Fig. 804.

and whose height is equal to that of the surface of the water above the valve *v* in the tube CE. Hence, after each stroke of the pump, the pressure on the piston and the force necessary to raise it, will be increased by the weight of a column of water whose base is the horizontal section of the piston, and its height equal to the increase which the elevation of the column in CE receives from the water driven through the valve *x*. In the figure *cd* is the piston, the bottom of whose rod is at *b*; *m* and *n* are rods which connect it with the upper part of the work, and WW is the level of the water in the well.

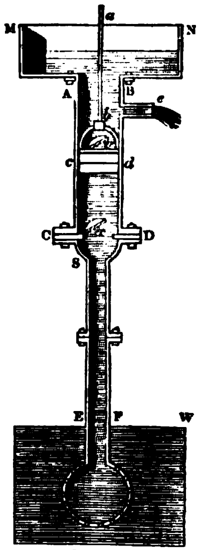


Fig. 805.

2221. The common, or as it is usually called, *suction pump* (shown in *fig.* 805.), is nothing more than a large syringe connected with a tube whose lower extremity is plunged in the well from which the water is to be raised. The tube is called a *suction pipe* (SO), and its end in the well is represented by O, which, for the purpose of preventing the ascent of solid impurities, that might choke the pipe and impede its action, is pierced with holes like a strainer. At the upper end of this suction pipe is placed the valve *x* opening upwards. At this place the tube is connected with another, BC, which acts as a great syringe, and in which works a piston having a valve at *v*, also opening upwards. The piston is worked alternately upwards and downwards in common pumps by a lever called the *brake*, but it may be worked in many ways. In the figure, W is the level of the water, CD the *flange*, where the lower valve is fixed, *cd* the piston, *ab* the piston rod, and MN the cistern into which the water is raised and delivered by its gravity at the *nozzle* of the pump *e*. At the commencement of the operation the water in the suction tube stands at the same height as the water in the well, being equally subject to the atmospheric pressure; but as soon as the syringe BC exhausts the air by the upward and downward action of the piston *cd*, the pressure of the air in SO being diminished and rendered less than that on the surface of the water in the well, will rise in SO by the atmospheric pressure; and as the air becomes more completely exhausted in the column of water in the tube SO below the valve *x*, so will its pressure on the surface of the column be diminished, and whilst that diminution goes on, the height of the column will increase. If the air could be entirely withdrawn from the tube SO, and a perfect vacuum created beneath the valve *x*, similar to that existing above the mercury in a barometer, then the atmospheric pressure, acting with undiminished effect on the surface of water in the well, would, in the tube SO, sustain a column of water equal to a column of mercury of the same base and of the same height as the mercury in the barometer. Now, the specific gravity of mercury being 13½ times greater than that of water, a force capable of sustaining a column of mercury 30 inches high, would sustain a column of water equal to 30 inches $\times 13\frac{1}{2} = 405$ inches $= 33\frac{9}{12}$ feet. But an absolute vacuum is never formed, and, moreover, in this country, as the barometric column varies between 28 and 31 inches in height, the valve *x* should on no account be more than 28 feet above the level of the water in the well, taking into consideration all the attendant circumstances. This is the construction and principle upon which the common household pump is formed, and in it no other aid is derived from atmospheric pressure than what we have already stated; hence the pump requires as much force to work it as, in general terms, is equal to the weight of all the water in it at any time, the atmospheric pressure affording no aid to the workman. The cistern at the top is placed for the purpose of affording an unintermitted discharge of the water by holding more than the whole accumulation of water which is contrived to be greater than the spout or nozzle will discharge.

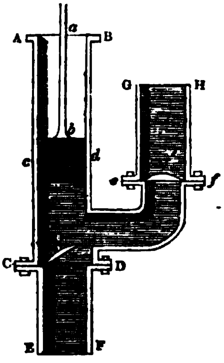


Fig. 806.

2222. The forcing pump, whose construction is shown in *fig.* 806., is a combination of the common suction and lifting pump. CEFD is a suction pipe descending into the well, and at its top is the valve V opening upwards. The pump barrel ABCD is furnished with a solid piston *cd*, whose rod is *ab*, without any valve. From the side of the barrel, just above the suction valve, a pipe proceeds, communicating with an upright cylinder GH, carried to such height as the water is intended to be raised. At the bottom of this cylinder is placed the valve V′ opening upwards. At the commencement of working, the suction pipe CE and the chamber between the piston and valves are filled with air. When the piston descends to the valve V, the air enclosed in the latter chamber becomes condensed, and opening, therefore, the valve V′, a part of it escapes through it. On raising the piston the air below it becomes partially exhausted, and that in the suction pipe, opening the valve V, by its greater pressure, expands into the upper chamber. A part of this is expelled when the piston next descends, by means of the valve V′. This action is similar to that of an air pump or exhausting syringe. When by the repetition of this action the air is sufficiently exhausted, the atmospheric pressure upon the water in the well causes the water to rise therefrom through the suction pipe and the valve V, into the chamber between the piston and the valves. When the piston next descends it presses on the surface of the water, and the valve V opening upwards prevents the return of the water into the suction pipe, while the pressure of the piston being transmitted by the water to the valve V′, opens it, and as the piston descends, the water passes into the force pipe GH. On the next ascent of the piston more water is allowed to pass through the valve V, and the next descent forces this water through the valve V into the force pipe. By repeating the action the quantity of water in the force pipe increases, receiving equal additions at each descent of the piston. It is obvious that the position of the force pipe is a matter of no moment; it may be perpendicular, oblique, or horizontal; for in each case the water will be propelled through it. When the piston is pressed downwards, and the valve V′ is opened, it is necessary that the force working the piston should balance the weight of the column of water in the force pipe, for this weight is transmitted by the water between the piston and force pipe to the bottom of the piston; the height, therefore, of the column of water in the force pipe will measure the intensity of the pressure against the base of the piston when the valve V′ is open. A column of water suspended 34 feet in height in the force pipe will press on the base of the piston with a force of about 15 pounds for each square inch; and the pressure at other heights will be proportional to this. Thus the force necessary to urge the piston downwards may always be calculated. The valve V′ is closed in drawing up the piston, and it then relieves the piston from the weight of the incumbent column. If the valve V is opened, the piston is subject to the same pressure as in the suction pump, and this has already been seen to be equal to the weight of a column of water raised above the level of the water in the well. From this it follows, that when the height of the force pipe is equal to the length of the suction pipe, the piston will be pressed upwards and downwards with equal forces; but when the height of the force pipe is greater or less than the length of the suction pipe, the downward pressure must be greater or less, in the same proportion, than the force which draws the piston up.

2223. The supply of water by the force pipe through the valve V′ is evidently intermitting, being suspended during the ascent of the piston; hence the flow from the point of discharge will be subject to the same intermission if means be not taken to counteract such effect. A cistern at the top of the force pipe, as already shown, for the suction pump, would answer the purpose; but it is found more convenient to use an apparatus called an *air vessel* (see *fig.* 807.), in which immediately above the valve V′ a short tube communicates with a strong close vessel of sufficient capacity, through the top whereof the force pipe GH passes, and descends to near the bottom. When the pump is in action the water is forced into the vessel MN, and when its surface, as at *ww*, rises above the mouth H of the force pipe, the air in the vessel MN is confined above the water; and as the water is gradually forced in, the air, being compressed, acts with increased elastic force on the surface of the water. This pressure forces a column of water into the pipe HG, and maintains it at an elevation proportional to the elastic force of the condensed air. When the air in the vessel MN is reduced to half its original bulk it will act on the surface of the water *ww* with double the atmospheric pressure; meanwhile, the water in the force pipe being subject to merely once the atmospheric pressure, there is an unresisted force upwards equal to the atmospheric pressure which sustains the column of water in the tube, and a column 34 feet high will thus be sustained. If the air is reduced to one third of its original bulk, the height of the column sustained will be 68 feet, and so on. If the force pipe were made to terminate in a ball pierced with small holes so as to form a *jet d'eau*, the elastic pressure of the air on the surface would cause the water to spout from the holes.

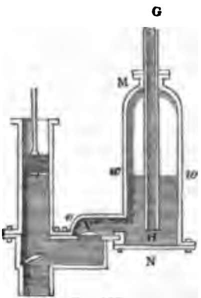


Fig. 807.

2224. In the formation of all pumps the parts should be nicely fitted, and as air-tight as possible, otherwise, in using them, much of the power employed will be lost. All expedients which tend to this great desideratum are of value; indeed any arrangement adapted to insure the perfect action of a pump is of the utmost importance for the comfort and convenience of small no less than large dwellings.

Sect. VIII.

GLAZING.

2225. Glazing, or the business of the glazier, consists in fitting glass in sashes, frames, and casements, either in putty or lead. It may be classed under the heads of *sashwork*, *leadwork*, and *fretwork*. Glass, as a material, has been already described in Chap. II. Sect. II. of this Book.

2226. The tools necessary for sashwork are — a *diamond*, polished to a cutting point, and set in brass in an iron socket, to receive a wooden handle, by which it is held in a cutting direction. The top of the handle goes between the root of the forefinger and middle finger, and the under part between the point of the forefinger and thumb. In general, there is a notch on the side of the socket, which should be held next the lath. Some diamonds have more *cuts* than one. Plough diamonds have a square nut on the end of the socket next the glass, which, on running the nut square on the side of the lath, keeps it in the cutting direction. Glass benders have their plough diamonds without long handles, as they cannot make use of a lath in cutting, but direct them by the point of their middle finger. The ranging lath should be long enough to extend beyond the boundary of the table of glass. *Ranging* of glass is the cutting it in breadths, and is best done by one uninterrupted cut from one end to the other. A *short lath* is used for stripping the square to suit the rebate of the sash, as in ranging they are generally cut full. A *square*, for the more accurate cutting at the right angles from the range. The carpenter's chisel is used in paring away some of the rebate of the sash when the glass does not lie so flat as to allow a proper breadth for front putty. The *glazing knife* is used for laying in the putty on the rebates, for bedding in the glass, and finishing the front putty. A *bradding hammer* is made with a head in the form of a small parallelopiped, with a socket for the handle, using it at an obtuse angle from the middle of one of its sides. The square edges of the head drive the brads in a horizontal direction, and with this tool there is less liability to accident than with any other. Some use the basil of the chisel for the purpose. *Brass points* are considered the best for bradding; *small cut brads* are also used. All new work should be bradded, to prevent the glass being moved out of its bed. The *duster* is a large brush for brushing the putties, and taking the oil from the glass. The *sash tool* is used wet, for taking the oil from the inside after the back putties are cleared off. The *hacking knife* is for cleaning out the old putty from the rebates where squares are to be stopped in. The use of the *glazier's rule* needs no explanation: it is 2 feet long, doubling in four different pieces.

2227. Leadwork for lights is often used for inferior offices, and frequently in country buildings. Frames made with crossbars receive these lights, which are fastened with leaden bars, called saddle bars. Where springs are wanted, a casement is introduced of wood or iron. Sometimes a sliding frame is used, particularly for church windows.

2228. The tool called the *glazier's vice* is for preparing the leaden slips with grooves, &c., to fit them for the reception of glass. The German vices are esteemed the best, and turn out a variety of lead in different sizes. There are moulds belonging to these vices in which bars of lead are cast; in this form the mill receives them, and turns them out with two sides parallel to each other, and about ⅜ of an inch broad, and a partition connecting the two sides together, about ⅛ of an inch wide, forming on each side a groove near 3/16 by ⅛ of an inch, and 6 feet long. The *setting board* is that on which the ridge of the light is worked, and divided into squares, and struck out with a chalk line, or drawn with a lath, which serve to guide the workman. One side and end is squared with a projecting bead or fillet. The *latterkin* is a piece of hard wood pointed, and so formed as to clear the groove of the lead, and widen it, for the more readily receiving the glass. The *setting knife* is a blade with a round end, loaded with lead at the bottom of the blade, and having a long square handle. The square end of the handle serves to force the squares home tight in the lead; being loaded with lead, it is of greater weight, and also cuts off the ends of the lead with greater ease, as in the course of working these lights the lead is always longer than is necessary till trimmed.

2229. The resin box contains powdered resin, which is put on all the joints previous to soldering. *Clips* are for holding the irons. All the intersections are soldered on both sides except the outside joints of the outer side, that is, where they come to the outer edge. These lights should be cemented, which is done by thin paint being run along the lead bars and the chasm filled with dry whiting. After it has stood a short time a small quantity of dry red or white lead is dusted over it, which will enable it to resist the weather well. *Fretwork* is the ornamental part of lead-light work, and consists in working ground or stained glass into different patterns and devices, as may be seen in the old stained glass windows.

2230. In London a large portion of the glazier's business consists in cleaning windows.

2231. The putty in which the glazier beds the glass is of four sorts. *Soft putty*, which is composed of flour, whiting, and raw linseed oil; *hard putty*, composed of whiting and boiled linseed oil; *harder putty*, the same ingredients as the last, with the addition of a small quantity of turpentine for more quickly drying it; *hardest putty*, composed of oil, red or white lead, and sand. The first of these putties is the most durable, because it forms an oleaginous coat on the surface, but it requires a long time for drying. The hard sorts are apt to crack if not soon well painted, and the hardest of them renders it difficult to replace a pane when broken; hence it is altogether unfit for hothouse and greenhouse work.

SECT. IX.

PLASTERING.

2232. In the finishing of our dwellings, the decoration owes much of its effect to the labours of the plasterer: it is in his department to lay the ceilings, and to give, by means of plaster, a smooth coat to the walls, so as to hide the irregularities left by the bricklayer and mason, and make them sightly and agreeable. He also, in the better sort of buildings, furnishes plain and decorated mouldings for the cornices and ceilings; and in the external parts, where stone is expensive or not to be procured, covers the exterior walls with stucco or other composition imitative of stone.

2233. The plasterer's tools are — a *spade* or *shovel* of the usual description; a *rake* with two or three prongs bent downwards from the line of the handle, for mixing the hair and mortar together; *stopping* and *picking out tools*; rules called *straight edges*; *wood models*; and *trowels* of two sorts and various sizes; namely, the *laying and smoothing tool*, consisting of a flat piece of hardened iron, about 10 inches long, and 2¼ inches wide, very thin, and ground to a semicircular shape at one end, but square at the other. Near the square end on the back of the plate a small iron rod is riveted, with two legs, whereof one is fixed to the plate, and a round wooden handle is adapted to the other. All the first coats of plastering are laid on with this tool, as is also the last, or *setting*, as it is technically called. The other sorts of trowels are of three or more sizes, and are used for *guaging* the *fine stuff* and plaster for cornices, mouldings, &c. The length of these trowels is, the largest about 7 inches in length on the plate, and the smallest 2 or 3 inches: they are of polished steel, converging gradually to a point, with handles of mahogany adapted to the heel or broad end with a deep brass ferrule.

2234. The stopping and picking out tools are of polished steel, of various sizes, about 7 or 8 inches long and half an inch broad, flattened at both ends, and somewhat rounded. They are used for modelling and finishing mitres and returns to cornices, as also for filling up and finishing ornaments at their joinings. There is also used a small instrument, which is a piece of thin fir 6 or 7 inches square, called a *hawk*, with a handle vertical to it, for holding small quantities of plaster.

2235. The composition used by the plasterer is a groundwork of lime and hair, on which, for the finish, a coating of finer material is laid. The sorts of it are various; as, for instance, white lime and hair mortar on bare walls; the same on laths as for partitions and plain ceilings; for renewing the insides of walls, roughcasting on laths; plastering on brickwork with finishing mortar, in imitation of stone work, and the like upon laths. For cornices and the decorations of mouldings, the material is plaster of Paris, one which facilitates the giving by casts the required form and finish to the superior parts of his work. The plasterer uses it also for mixing with lime and hair, where the work is required to dry and set hard in a short time. For inside work, the lime and hair, or *coarse stuff*, is prepared, like common mortar, with sand; but in the mixing, hair of the bullock, obtained from the tanners' yards, is added to it, and worked in with the rake, so as to distribute it over the mass as equally as possible.

2236. What is called *fine stuff* is made of pure lime, slaked with a small quantity of water, and afterwards, without the addition of any other material, saturated with water, and in a semi-fluid state placed in a tub to remain until the water has evaporated. In some cases, for better binding the work, a small quantity of hair is worked into the composition. For interior work, the fine stuff is mixed with one part of very fine washed sand to three parts of fine stuff, and is then used for *trowelled* or *bastard stucco*, which makes a proper surface for receiving painting.

2237. What is called *guage stuff* is composed of fine stuff and plaster of Paris, in proportions according to the rapidity with which the work is wanted to be finished. About four-fifths of fine stuff to one of the last is sufficient, if time can be allowed for the setting. This composition is chiefly used for cornices and mouldings, run with a wooden mould. We may here mention that it is of the utmost importance, in plasterers' work, that the lime should be most thoroughly slaked, or the consequence will be blisters thrown out upon the work after it is finished. Many plasterers keep their stuffs a considerable period before they are wanted to be used in the building, by which the chance of blistering is much lessened.

2238. When a wall is to be plastered, it is called *rendering*; in other cases the first operation, as in ceilings, partitions, &c., is *lathing*, nailing the laths to the joists, quarters, or battens. If the laths are oaken, wrought iron nails must be used for nailing them, but cast iron nails may be employed if the laths are of fir. The lath is made in three and four foot lengths, and, according to its thickness, is called *single*, something less than a quarter of an inch thick, *lath and half*, or *double*. The first is the thinnest and cheapest, the second is about one-third thicker than the single lath, and the double lath is twice the thickness. When the plasterer laths ceilings, both lengths of laths should be used, by which, in nailing, he will have the opportunity of breaking the joints, which will not only help in improving the general *key*, (or plastering insinuated behind the lath, which spreads there beyond the distance that the laths are apart,) but will strengthen the ceiling generally. The thinnest laths may be used in partitions, because in a vertical position the strain of the plaster upon them is not so great; but for ceilings the strongest laths should be employed. In lathing, the ends of the laths should not be lapped upon each other where they terminate upon a quarter or batten, which is often done to save a row of nails and the trouble of cutting them, for such a practice leaves only a quarter of an inch for the thickness of the plaster; and if the laths are very crooked, which is frequently the case. sufficient space will not be left to straighten the plaster.

2239. After lathing, the next operation is *laying*, more commonly called *plastering*. It is the first coat on laths, when the plaster has two coats or set work, and is not scratched with the scratcher, but the surface is roughed by sweeping it with a broom. On brickwork it is also the first coat, and is called rendering. The mere laying or rendering is the most economical sort of plastering, and does for inferior rooms or cottages.

2240. What is called *pricking up* is the first coat of three-coat work upon laths. The material used for it is coarse stuff, being only the preparation for a more perfect kind of work. After the coat is laid on, it is scored in diagonal directions with a *scratcher* (the end of a lath), to give it a key or tie for the coat that is to follow it.

2241. *Lath layed* or *plastered and set* is only two-coat work, as mentioned under laying, the setting being the guage or mixture of putty and plaster, or, in common work, of fine stuff, with which, when very dry, a little sand is used; and here it may be as well to mention, that *setting* may be either a second coat upon laying or rendering, or a third coat upon *floating*, which will be hereafter described. The term finishing is applied to the third coat when of stucco, but setting for paper. The setting is spread with the smoothing trowel, which the workman uses with his right hand, while in his left he uses a large flat-formed brush of hog's bristles. As he lays on the putty or set with the trowel, he draws the brush, full of water, backwards and forwards over its surface, thus producing a tolerably fair face for the work.

2242. Work which consists of three coats is called *floated*: it takes its name from an instrument called a *float*, which is an implement or rule moved in every direction on the plaster while it is soft, for giving a perfectly plane surface to the second coat of work. Floats are of three sorts: the *hand float*, which is a short rule, that a man by himself may use; the *quirk float*, which is used on or in angles; and the *Derby*, which is of such a length as to require two men to use it. Previous to floating, which is, in fact, the operation of making the surface of the work a perfect plane, such surface is subdivided in several bays, which are formed by vertical styles of plastering, (three, four, five, or even ten feet apart,) formed with great accuracy by means of the plumb rule, all in the same plane. These styles are called *screeds*, and being carefully set out to the coat that is applied between them, the plaster or floating laid on between them is brought to the proper surface by working the float up and down on the screeds, so as to bring the surface all to the same plane, which operation is termed *filling out*, and is applicable as well to ceilings as to walls. This branch of plastering requires the best sort of workmen, and great care in the execution.

2243. *Bastard stucco* is of three coats, the first whereof is roughing in or rendering, the second is floating, as in trowelled stucco, which will be next described; but the finishing coat contains a small quantity of hair behind the sand. This work is not hand-floated, and the trowelling is done with less labour than what is denominated trowelled stucco.

2244. *Trowelled stucco*, which is the best sort of plastering for the reception of paint, is formed on a floated coat of work, and such floating should be as dry as possible before the stucco is applied. In the last process, the plasterer uses the hand float, which is made of a piece of half-inch deal, about nine inches long and three inches wide, planed smooth with its lower edges a little rounded off, and having a handle on the upper surface. The ground to be stuccoed being made as smooth as possible, the stucco is spread upon it to the extent of four or five feet square, and, moistening it continually with a brush as he proceeds, the workman trowels its surface with the float, alternately sprinkling and rubbing the face of the stucco, till the whole is reduced to a fine even surface. Thus, by small portions at a time, he proceeds till the whole is completed. The water applied to it has the effect of hardening the face of the stucco, which, when finished, becomes as smooth as glass.

2245. From what has been said, the reader will perceive that mere laying or plastering on laths, or rendering on walls, is the most common kind of work, and consists of one coat only; that adding to this a setting coat, it is brought to a better surface, and is two-coat work; and that three-coat work undergoes the intermediate process of floating, between the rendering or pricking up and the setting.

2246. Ceilings are *set* in two different ways; that is the best wherein the setting coat is composed of plaster and putty, commonly called guage. Common ceilings are formed with plaster without hair, as in the finishing coat for walls set for paper.

2247. *Pugging* is plaster laid on boards, fitted in between the joists of a floor, to prevent the passage of sound between two stories, and is executed with coarse stuff.

2248. The following materials are required for 100 yards of render set; viz. 1½ hundred of lime, 1 double load of river sand, and 4 bushels of hair; for the labour, 1 plasterer 3 days, 1 labourer 3 days, 1 boy 3 days; and upon this, 20 per cent. profit is usually allowed. For 130 yards of lath plaster and set — 1 load of laths, 10,000 nails, 2½ hundred of lime, 1½ double load of river sand, 7 bushels of hair; for the labour, 1 plasterer 6 days, 1 labourer 6 days, 1 boy 6 days; and upon this, as before, 20 per cent. is usually allowed.

2249. In the country, for the exterior coating of dwellings and out-buildings, a species of plastering is used called *roughcast*. It is cheaper than stucco or Parker's cement, and therefore suitable to such purposes. In the process of executing it, the wall is first pricked up with a coat of lime and hair, on which, when tolerably well set, a second coat is laid on of the same materials as the first, but as smooth as possible. As fast as the workman finishes this surface, another follows him with a pailful of the roughcast, with which he bespatters the new plastering, so that the whole dries together. The roughcast is a composition of small gravel, finely washed, to free it from all earthy particles, and mixed with pure lime and water in a state of semi-fluid consistency. It is thrown from the pail upon the wall, with a wooden float, about 5 or 6 inches long, and as many wide, formed of half-inch deal, and fitted with a round deal handle. With this tool, while the plasterer throws on the roughcast with his right hand, in his left he holds a common whitewasher's brush dipped in the roughcast, with which he brushes and colours the mortar and the roughcast already spread, to give them, when finished, an uniform colour and appearance.

2250. In forming the coves and cornices which are applied below the ceilings of rooms, it is of the greatest importance to make them as light as possible, for the plaster whereof they are formed is heavy, and ought not to be trusted merely to its adhesion to the vertical and horizontal surfaces to which it is attached. Hence, when cornices run of large dimension, bracketing, as has already been described in the section Joinery (2079, *et seq.*), must be provided, of the general form of the cornice or cove, or other work, and on this the plastering is to be formed. On this, when roughed out, the work is run with wooden moulds, having brass or copper edges, so as to give the general outline of the cornice. If enrichments are used in it, they are cast in plaster of Paris, and afterwards fixed with that material in the spaces left for them to occupy. These enrichments are previously modelled, and from the model a matrix is formed, as for all other plaster casting. Great nicety is required in all the operations relative to the moulding and fixing of cornices, and most especially that the ornaments be firmly fixed, that they may not be detached from their places by partial settlements of the building, and cause accidents to the occupiers of the rooms where they are used.

2251. In the present time, the use of ornaments made of carton-pierre, a species of papier maché has been reintroduced for cornices, flowers, and other decorations. The basis of it is paper reduced to a pulp, which having other ingredients mixed with it is pressed into moulds, and thus ornaments are formed of it. Though they have not all the delicacy of the plaster cast, their lightness, and the security with which they can be fixed with screws is such, that we have no hesitation in recommending them for adoption, in preference to plaster ornaments; and, indeed, their general use at present warrants the recommendation we here give. At the same time, we must caution the architect that the thing is at present far from the perfection to which the plasterer carries his practice, and that in the fixing there is all the want of that nicety which a good cornice workman in plaster exhibits. There has been a great want of competition in this country of the manufacture of carton-pierre. Indeed of what is made here the modelling is generally very bad, inferior artists being employed upon it. That manufactured by Waillet and Huber of Paris we have found to be the best, and their modellers are able artists. We have already adverted to the cements used in plastering. Parker's, Bailey's, Atkinson's, and Chambers's are the principal ones for coating buildings, and the process of laying them on is so similar to that of other plasterer's work, that it will not be necessary to say more than that they are all good, and may be used with safety.

2252. It is scarcely within the branch of the plasterer's practice, but as we shall have no other place for adverting to it, we may as well here mention a composition which, till lately, was much in use, but will certainly now be entirely superseded by the carton-pierre, above mentioned; we mean what are called composition ornaments, which were never, however, used in cornices, but principally for the decoration of an inferior class of chimney-pieces, and the like. The composition is very strong when dry, of a brownish colour, consisting of about two pounds of powdered whiting, a pound of glue in solution, and half a pound of linseed oil mixed together in a copper, heated and stirred with a spatula till the whole is incorporated. After heating it is laid upon a stone covered with powdered whiting, and beaten to a tough and firm consistence, when it is laid by for use, covered with wet cloths to keep it fresh. This composition is then put into a press, and pressed into moulds made of boxwood. It is now, however, nearly abandoned, as it ought to be, its weight being so much against its use.

Sect. X.

SMITHERY AND IRONMONGERY.

2253. Smithery is the art of uniting several lumps of iron into one lump or mass, and forming them into any desired shape. The operations necessary for this are primarily performed in the forge, and on the anvil with the hammer; but for finishing, many other implements and tools are necessary. These, however, we do not think useful to particularise, a course we have pursued in the other trades, because the expedients introduced by the engineer and machinist have of late years, except in rough work, superseded many of them. It is now, for instance, easier to plane iron to a perfect surface than it was a few years ago to file or hammer to what was then always an imperfect one. Formerly a man would be occupied as many minutes in drilling a hole as by machines it now takes seconds to perform.

2254. We have, in a previous section, given all the particulars relating to the produce of the metal from the ore; in this section we propose little more than to enumerate the different objects which the smith and ironmonger furnish in the construction of buildings; and introductory to that it will be convenient to subjoin tables of the weights of round and bar iron, and also of the weights of 1 foot of close hammered bar iron of different thicknesses; remembering that a cube foot of close hammered iron weighs about 495 lbs., of common wrought iron about 480 lbs., and of cast iron 450 lbs., whence may be derived the weight of other solids whose cubic contents are known.

Table showing the Weight of one Foot in length of a square Iron Bar.

Side of Square in inches.	Weight in lbs. averdupois.	Side of Square in inches.	Weight in lbs. averdupois.
¼	0·1875	2⅛	15·0625
⅜	0·4687	2¼	16·8740
½	0·8125	2⅜	18·8125
⅝	1·2812	2½	20·8125
¾	1·8740	2⅝	22·9687
⅞	2·5625	2¾	25·1875
1	3·3125	2⅞	27·7500
1⅛	4·2187	3	30·0000
1¼	5·1875	3⅛	32·5312
1⅜	6·3125	3¼	35·1875
1½	7·5000	3⅜	37·9687
1⅝	8·8125	3½	40·7812
1¾	10·1875	3⅝	43·7812
1⅞	11·7187	3¾	46·8740
2	13·3125	3⅞	50·0520
		4	53·3125

Table showing the Weight of one Foot in length of a round Iron Bar.

Diameter in inches.	Weight in lbs. averdupois.	Diameter in inches.	Weight in lbs. averdupois.
¼	0·1562	2⅛	11·8125
⅜	0·3750	2¼	13·2500
½	0·6562	2⅜	14·7500
⅝	1·0000	2½	16·3437
¾	1·4687	2⅝	18·0000
⅞	2·0000	2¾	19·7812
1	2·5937	2⅞	21·6250
1⅛	3·3125	3	23·5625
1¼	4·0937	3⅛	25·5625
1⅜	4·9375	3¼	27·6562
1½	5·9375	3⅜	29·8125
1⅝	6·9052	3½	32·0625
1¾	8·0000	3⅝	34·4062
1⅞	9·1875	3¾	36·8125
2	10·4607	3⅞	39·3116
		4	41·8740

TABLE SHOWING THE WEIGHT OF *close-hammered* FLAT BAR IRON, FROM ONE INCH WIDE AND AN EIGHTH OF AN INCH THICK TO FOUR INCHES WIDE AND ONE INCH THICK.

Inches, and their Parts in breadth.	Thickness in Parts of an Inch, and Weight in Pounds averdupois.							
	⅛	¼	⅜	½	⅝	¾	⅞	1
1	0·429	0·859	1·289	1·718	2·148	2·578	3·007	3·437
1⅛	0·484	0·968	1·503	1·937	2·422	2·905	3·383	3·868
1¼	0·539	1·078	1·639	2·148	2·682	3·226	3·758	4·305
1⅜	0·593	1·187	1·773	2·368	2·953	3·547	4·133	4·726
1½	0·648	1·289	1·937	2·579	3·218	3·867	4·508	5·156
1⅝	0·695	1·398	2·093	2·789	3·492	4·187	4·890	5·585
1¾	0·750	1·500	2·250	3·008	3·758	4·508	5·266	6·016
1⅞	0·804	1·609	2·414	3·218	4·281	4·835	5·641	6·445
2	0·859	1·699	2·578	3·437	4·297	5·156	6·016	6·874
2⅛	0·913	1·828	2·742	3·356	4·562	5·476	6·391	7·305
2¼	0·948	1·937	2·897	3·867	4·835	5·805	6·766	7·734
2⅜	1·023	2·039	3·062	4·148	5·101	6·125	7·148	8·164
2½	1·069	2·148	3·218	4.297	5·375	6·445	7·547	8·594
2⅝	1·125	2·250	3·383	4·516	5·641	6·766	7·897	9·023
2¾	1·179	2·366	3·500	4·726	5·905	7·093	8·273	9·443
2⅞	1·234	2·468	3·721	4·937	6·180	7·414	8·648	9·882
3	1·289	2·578	3·867	5·156	6·445	7·734	9·023	10·312
3⅛	1·344	2·687	4·031	5·375	6·734	8·055	9·398	11·742
3¼	1·398	2.789	4·187	5·609	6·984	8·375	9·773	11·172
3⅜	1·443	2·905	4·335	5·805	7·250	8·703	10·156	11·601
3½	1·500	3·007	4·508	6·016	7·516	9·039	10·503	12·031
3⅝	1·562	3·117	4·672	6·226	7·789	9·344	10·905	12·461
3¾	1·609	3·218	4·860	6·445	8·062	9·664	11·281	12·890
3⅞	1·630	3·328	5·000	6·656	8·328	9·992	11·656	13·320
4	1·718	3·437	5·156	6·874	8·593	10·312	12·031	13·750
8	3·436	6·874	10·312	13·748	17·186	20·624	24·062	27·400
12	5·156	10·312	15·469	20·625	25·781	30·937	36·094	41·250
If of Cast Iron.								
12	4·835	9·664	14·500	19·336	24·172	29·000	33·836	38·672

2255. For the carcass of a building the chief articles furnished by the smith are *chimney bars*, which are wide thin bent bars or plates of iron, to relieve the weight of brickwork over wide openings of chimneys, as in kitchens and rooms where a large area of fire is requisite. In these situations they are subject however to objection, because of their liability to constant expansion and contraction from the varying temperature, which often produces fractures about the chimney jambs. They nevertheless, on the whole, produce a security which sanctions their use. *Cramps* for holding together courses of stonework. These, however, are better of cast iron, being far less subject to decay by oxidisation. *Balusters and railing* for stairs and the areas of houses towards a public way. *Shoes for piles*, when that mode of obtaining a foundation is adopted. *Wrought iron columns with caps and bases*, for the support of great superincumbent weights. Cast iron are now preferred both for economy and stiffness; as is also that material for girders and bressumers, which have been already disposed of in a previous page. *Area gratings and window bars* for securing the lower stories of houses. Here, again, the founder has stept in to render the employment of wrought iron much less general than formerly. *Ties* of all descriptions, and for the carpenter especially the various sorts of *straps*, *bolts*, *nuts and screws*, *plates*, *washers*, and the like, for connecting the pieces in framing where the strain is greater than the mere fibres of the wood will resist. *Casements*, with their fastenings for lead lights, are also furnished by the smith. But he is now rarely employed, as heretofore, for fancy gates, sashes, and frames, such works being furnished by the founder, as well as rain-water pipes with their cistern heads, pavement gutters, air traps, scrapers, coalplates, water-closet traps, and a number of other objects which will occur to the reader.

2256. The chief articles furnished by the ironmonger are for the joiner's use, and, except in particular cases, are kept in store by that tradesman for immediate supply as required.

2257. They consist in *screws*, whose common sizes are from three quarters of an inch up to 4 inches in length. They are sold by the dozen.

2258. *Iron butt hinges*, whose name is probably derived from their butting close surface to surface when closed, used for hanging doors and shutters. They are made both of iron and brass, the former varying in size from 1½ to 4 inches in length; the latter from 1 inch to 4 inches. These, as well as all other hinges, are in size necessarily proportioned to the magnitude and consequent weight of the shutters or doors they are to carry; and it is to be observed, that for the well-hanging of a door or shutter, the size of the hinge should be rather on the outside of enough than under the mark. There is a species of hinge used for doors called the *rising joint hinge*, a contrivance in which the pivot, having on it a short portion of a spiral thread, and the part to which the door is fixed having a correspondent mass, the door in opening rises, and clears the carpet or other impediment usually placed on the floor. The *projecting brass butt* is used when the shutter or door is required to clear some projection, and thus, when opened, to lie completely back in a plane parallel to its direction when shut. All hinges are purchased from the ironmonger by the pair.

Besides the hinges above mentioned are those called *cross garnets*, whose form is ⊢, that of a T lying sidewise. These are only used on the commonest external doors, and are made from 10 to 20 inches, varying in their dimensions by differences of two inches. H *hinges*, the shape of the letter H, showing their form as well as the origin of their name. These in their sizes range from 3 to 8 inches by differences of an inch. HL *hinges* (H and L conjoined), whose form is implied by their name, and whose sizes are from 6 to 12 inches, proceeding by inches. *Parliament hinges* are made of cast and wrought iron, from 3½ to 5 inches, proceeding in size by half inches.

2259. *Rough rod bolts* are those in which there is no continued barrel for the bolt, and are for the most common service. Their sizes begin with a length of three inches, and proceed by inches up to a length of 10 inches; such, at least, are their common sizes. *Bright rod bolts* run of the same sizes as the last; and, as the name indicates, the bolt is polished and finished, so as to make them a better fastening, as far as appearance is concerned. The *spring plate bolt* is contrived with a spring to keep the bolt up to its work, but one which so soon gets out of order that we wonder it is now manufactured or used. It is made of lengths from 3 to 8 inches, by variations of an inch in size. *Barrelled bolts* are those in which the whole length of the bolt is enclosed in a continued cylindrical barrel, and are superior to all others in use, as well as the most finished in their appearance. Their common sizes are from 6 to 12 inches, varying by steps of an inch. All the bolts above mentioned are sold per piece by the ironmonger, as are those called *flush bolts*, a name given to such as are let into the surface to which they are applied, so as to stand flush with it. They are mostly made of brass, and are of two different thicknesses, viz. half and three quarter inch. Their lengths vary from 2½ to 12 inches, and occasionally, as circumstances may require, as in book-case doors and French sashes, to a greater length. But for French casements, what is called the *Espaniolette bolt*, a contrivance whose origin is French, though much improved in its manufacture here, is now more generally in use.

2260. *Pullies*, for hanging sashes and shutters, are made of iron or brass, or with brass sheaves or brass axles. Their sizes are from one inch and a half to two inches and a half in diameter.

2261. The varieties of locks, their contrivances for security, and their construction, are so many, that to describe them minutely would require almost a work of itself. All that the architect has to deal with, for common purposes in building, we shall mention. For fastening places where particular security is requisite, as strong closets for plate or cash, some of the patented locks should be used, and we must leave this matter for inquiry in the hands of the architect. Every patentee says his invention is the best. We nevertheless believe, notwithstanding the boasts of all the inventors, no lock has yet appeared which an expert locksmith acquainted with its construction will not be able to pick. The locks in common use are *stock locks*, whose box is usually of wood, and whose sizes vary from 7 to 10 inches. *Dead locks*, whose sizes are from 4 to 7 inches, and so called from the key shooting the bolt home *dead*, without a spring. *Cupboard locks* of 3, 3½, and 4 inches in size. *Iron rim locks*, whose box or case is made of iron, and which are fitted on to one of the sides of a door, and whose sizes are from 6 to 8 inches. Of those made of the last-named size, there are some, as also of 9 inches, which are used for external doors, called *iron rim drawback locks*. For the doors of all well-finished apartments, *mortice locks* are used. These take their name from being morticed into the thickness of the door, and being thus hidden. To these either plain or fancy *furniture*, that is, nobs and escocheons, are affixed. Above and below them *finger plates* are generally directed to be placed, to prevent the door being soiled in the places where it is mostly laid hold of.

2262. The different sorts of latches in use are the *thumb latch*, which receives its name from the thumb being placed on the lever to raise its latch; the *Norfolk latch*; the four-inch *bow latch* with brass nobs; the brass *pulpit latch*; and the *mortice latch*.

2263. Besides the articles already mentioned, *spikes, holdfasts*, and *wall hooks, door springs* of various sorts, *door chains* and *barrels, thumb screws* and other shutter and sash fastenings, *brass turn buckles, closet knobs, brass flush rings, shutter bars, brass rollers, bars with latchets, shelf brackets, drawer handles, wrought iron bars, sash lines and weights*, besides many others, are furnished by the ironmonger. In treating on specifications, in a subsequent section, it will be seen how the several articles of smithery and ironmongery are applied.

2264. Bolts, straps, and other exposed iron-work are preserved from the action of moisture on them by the following mixture: — To two quarts of boiling oil add half a pound of litharge, putting in small quantities at a time, and cautiously. Let it simmer over the fire two or three hours; then strain it, and add a quarter of a pound of finely-pounded resin and a pound of white lead, keeping it at a gentle heat till the whole is well incorporated. It is to be used hot. A composition of oil and resin and finely levigated brickdust is found useful in preserving iron from rust. It is to be mixed, and used as a paint of the usual consistence.

SECT. XI.

FOUNDERY.

2265. The very general use of cast iron by the architect has induced us to give, in a previous section, a succinct account of the common operations of foundery, or the art of casting metal into different forms. We do not think it necessary, therefore, to do more than refer the reader to Chap. II. Sect V. of this Book (1763, *et seq.*). The foundery of statues, which is among the most difficult of its branches, belongs exclusively to the sculptor, and is usually carried on in bronze.

2266. To gain a proper knowledge of the operations of the founder, the student should attend a few castings at the foundery itself, which will be more useful to him than all which in words we can express on the subject.

SECT. XII.

PAINTING, GILDING, AND PAPER-HANGING, ETC.

2267. Painting is the art of covering the surfaces of wood, iron, and other materials with a mucilaginous substance, which, acquiring hardness by exposure to the air, protects the material to which it is applied from the effects of the weather.

2268. The requisite tools of the painter are — *brushes of hog's bristles*, of various sizes suitable to the work; a *scraping or pallet knife*; *earthen pots* to hold the colours; a *tin can* for turpentine; a *grinding stone and muller*, &c. The stone should be hard and close-grained, about 18 inches in diameter, and of sufficient weight to keep it steady. The knots, especially of fir, in painting new work, will destroy its good effect if they be not first properly *killed*, as the painters term it. The best way of effecting this is by laying upon those knots which retain any turpentine a considerable substance of lime immediately after it is slaked. This is done with a stopping knife, and the process dries and burns out the turpentine which the knots contain. When the lime has remained on about four and twenty hours, it is to be scraped off, and the knots must be painted over with what is called *size knotting*, a composition of red and white lead ground very fine with water on a stone, and mixed with strong double glue size, and used warm. If doubts exist of their still remaining unkilled, they may be then painted over with red and white lead ground very fine in linseed oil, and mixed with a portion of that oil, taking care to rub them down with sand paper each time after covering them when dry; so that they may not appear more raised than the other parts. When the knotting is completed, the *priming colour* is laid on. The priming colour is composed of white and a little red lead mixed thin with linseed oil. One pound of it will cover from 18 to 20 yards. When the primer is quite dry, if the work is intended to be finished white, mix white lead and a very small portion of red with linseed oil, adding a little quantity of spirits of turpentine for second colouring the work. Of this second primer, one pound will cover about 10 to 12 square yards. The work should now remain for some days to harden; and before laying on the third coat, it should be rubbed down with fine sand paper, and stopped with oil putty wherever it may be necessary. If the knots still show through, they should be covered with silver leaf laid on with japanned gold size. The third coat is white lead mixed with linseed oil and turpentine in equal portions, and a pound will cover about 8 square yards. If the work is not to be finished white, the other requisite colour will of course be mixed with the white lead, as in the case of four coats being used. When the work is to be finished with four coats, the finishing coat should be of good old white lead as the basis, thinned with bleached linseed oil and spirits of turpentine; one of oil to two of turpentine. If the work is to be finished *dead white*, the very best old lead must be used, and thinned entirely with spirits of turpentine.

2269. When stucco is to be painted, it will require one more coat than wood-work; the last coat being mixed, if the work is as usually executed, with half spirits of turpentine and half oil, for the reception of the finishing coat of all turpentine or flatting. If the work be not flatted, the finishing coat should be with one part oil and two of turpentine. It would be impossible to enter into the details which are to be observed in painting walls of fancy colours; all that can be said on this point in instruction to the architect is, that when fancy colours, as they are called, which in these days a painter construes as anything but white and a tinge of ochre or umber, each coat must incline, as it is laid on, more and more to the colour which the work is intended to bear when finished.

2270. In repainting old work, it should be well rubbed down with dry pumice stone, and then carefully dusted off, and when requisite, the cracks and openings must be well stopped with oil putty. After this, a mixture of white, with a very small portion of red lead, with equal parts of oil and turpentine, is used to paint the work, which the painters technically call second colouring old work. After this, the work being dry, a mixture of old white lead, adding a small portion of blue black in a medium of half bleached oil and half turpentine, is used for finishing, or, if flatting be intended, the former preparation will be suitable for receiving dead white or any fancy colour. The same process will serve for stuccoed walls, observing that, if more coats be required, the mixture of half oil and half turpentine is proper.

2271. In respect to outside work, the use of turpentine is to be avoided, for turpentine is more susceptible of water than oil, and thence not so well calculated to preserve work exposed to the weather. Oil, however, having from its nature a natural tendency to discolour white, that is necessarily finished with a portion of half oil and half turpentine; but in dark colours this is not necessary, and in such cases, boiled oil, with a little turpentine, is the best, or indeed boiled oil only.

2272. White lead is the principal basis of all stone colours. If the finishing colour is white, nothing but white lead should be employed. Lead colours are formed by a mixture of white lead with lamp black; all colours, however, that are called *fancy colours*, have white lead for their basis, chocolates, black, brown, and wainscot only excepted.

2273. There is a process used by painters, termed *clear-coaling*, which is executed with white lead ground in water, and mixed with size. This is used instead of a coat of paint; but it has not sufficient body usefully to answer the end for which it is usually employed. It scales off, and in damp situations its colour almost immediately changes. The only occasions wherein it is useful, are where the work is greasy and smoky, in which the use of it prepares better for the reception of paint. It should, however, never be employed upon joiner's work or cornices to ceilings, where much enrichment is found; for of all things, it destroys the sharpness and beauty of the ornaments. Painters are very fond of using it; but their endeavours to persuade the architect should always be resisted, except in cases of absolute necessity, namely, that in which a fair appearance cannot otherwise be given to the work. Some colours dry badly, black especially, and in damp weather they require a *drier*, as it is called, which may be made from equal parts of copperas and litharge, ground very fine, and added according to circumstances.

2274. Drying oil is made as follows: — To 1 gallon of linseed oil, put 1 lb. of red lead, 1 lb. of umber, and 1 lb. of litharge, and boil them together for two or three hours. Great care must be taken that the oil does not boil over, on account of the danger to which the premises would be thereby exposed. Thus, in a pot capable of holding fifteen gallons, it would not be prudent to boil more than one-third of that quantity.

2275. Painters' putty is made of whiting and linseed oil, well beaten together.

2276. The extra or fancy colours used in painting are drabs, French greys, peach blossom, lilac, light greens, patent greens, blues, vermilion, lake, &c. All imitations, too, of woods and marbles, are executed by the painter, and these are always covered with one or more coats of varnish.

2277. In outside work and stairs, the process of *sanding* is frequently adopted. It is performed with fine sand thrown on the last coat of paint while wet. The method of gilding is either through a medium of oil or water, the former being that most used in gilding the decorations of houses. The gold, of various thickness, is furnished by the goldbeater in books of 25 leaves, each leaf being 3⅛ by 3 in., or in the book, 1 ft. 6 in. and ⅝ of an inch superficial.

2278. With painting is often connected the practice of paper-hanging by the same artificer. The various sorts of paper used for lining walls, it would be useless to describe. We have only to mention that papers are printed in pieces of 12 yards in length, and 1 foot 8 inches wide; hence, 1 yard in length contains 5 feet superficial; therefore, any number of superficial feet divided by 60 (the length 36 × 1 ft. 8 ins.) will give the number of pieces wanted for the work. A ream of printed paper of 20 quires of 24 sheets to the quire is equal to 28 pieces of paper, or each piece contains 17 sheets.

SECT. XIII.

SPECIFICATIONS.

2279. The importance of an accurate specification or description of the materials and work to be used and performed in the execution of a building, is almost as great as the preparation of the designs for it. The frequent cost of works above the estimated sum, and its freedom from extra charges on winding up the accounts, will mainly depend on the clearness, fulness, and accuracy of the specifications; though it is but justice to the architect to state that extras arise almost as often from the caprice of his employer during the progress of the work, as from the neglect or carelessness of the architect in making the specification. A specification should be made in all cases of new designs, additions, or alterations in reference to designs, which, the more they are given in working drawings by the architect, the better will it be for his employer, no less than for the artificer.

2280. It is impossible to frame a set of directions which shall be applicable in all cases. What we here propose to do is, to give something like a list or skeleton of the component parts of buildings, from which the architect may select such as are suitable to the particular case whereon he may be engaged. We have not carried this into the repairs and alterations of houses, because, with difference of application, we apprehend what we are placing before the student will enable him to carry the system forward in such cases without any difficulty. The works of each artificer are as follow: —

2281. **EXCAVATOR.** To take down any old buildings and impediments that may be on the site of the new works. If any old materials are to be used again, he is to clean, sort, and stack them for re-using in such parts of the premises as may be directed. The rubbish, as well from these as from any superfluous earth that may come out of the basement and foundations, if not wanted for raising the ground or for other purposes, he is to cart away, either wholly, or to such part of the premises as may require it, on direction to that effect, as well as all rubbish that may accumulate in executing the works.

To dig out for basement story (where one is to be) for the foundations, areas, drains, floors, and all other works requisite. To beat down to a solid consistence the ground forming the beds of the trenches for receiving the foundations and walls, and after they are in, he is to fill in and ram down the ground with wooden rammers; to level, and to do such other rough groundwork as may be necessary for forming the sectional ground lines shown upon the drawings. In basements no earth is to be left nearer than 9 inches to any floor or other timbers, such cavities being by the specification to be filled in with dry lime core. And, finally, he is to leave the ground altogether free from all useless soil or other materials.

To bale out or pump out and remove all soil and water which may be necessary for laying the foundations, whether arising from springs, drains, cesspools, rain, or otherwise, and to be answerable for all accidental damage that may occur whilst the foundations and walls are carrying up, as also, when buildings adjoin, for all damage that may occur to neighbouring buildings.

2282. **BRICKLAYER.** The brickwork is to be executed with the very best hard well-burnt *grey stocks* (*or kiln-burnt red stock bricks, if the others are not to be had*), to be laid in flat joints, and so that every four courses shall not exceed 11¼ inches in height.

When better bricks are used for *facing* external walls, they are to be specified as *best marle stocks*, *second marle stocks*, or *Suffolk white bricks*, as the case may be, in which case it must be specified that no headers of the facing are to be cut off, except where absolutely necessary to form good bond. Fronts so faced must be described to be either carried up with a neat flat parallel ruled joint, or to be afterwards tuck-joint pointed if a very finished face is wanted, though the latter is not altogether a very sound practice. In old work the joints may be described to be raked out, the brickwork washed, stained, and tuck-joint pointed.

No *place* or *samile* bricks to be allowed in any part of the work, under a penalty of two shillings for every such brick that may be detected to have been used.

The *mortar* is to be compounded of stone lime and sharp clean drift sand (if the work be of importance), to be ground in a pug-mill, or otherwise to be well tempered and beaten with wooden beaters, and to be in the proportion of one heaped bushel of lime to two of sand.

BRICKLAYER.

When the foundations are bad, *concrete* should be provided, and is thus described: it is to be formed in the proportion of six parts of Thames or other unscreened clean ballast, and one part of fresh-burnt Dorking (or other) *stone* lime, beaten to powder on the premises, and unslaked. They are to be thoroughly mixed in small quantities at a time, the lime at mixing being slaked with as small a quantity of water as possible. The concrete, after mixing, is to be dropped from a stage to be formed by the contractor, so as to fall into the trench provided for its reception from a height of at least 12 feet. The thickness of the conrete thus executed may vary from 4 feet to 18 inches in height, according to the badness or goodness of the foundation.

English bond should be directed, and the work should be specified to be flushed up at every course with mortar. No bats to be allowed except for closures; and for sound work every fourth course to be *grouted* with liquid mortar, and in the foundations every course, or at least every second course. The walls, chimneys, their shafts and other works are to be carried up of the height and thicknesses and in the manner shown and figured on the several plans and drawings, together with all brickwork requisite for the completion of the house. If the architect prefers, he may particularise these, but the drawings will show his meaning better. When the work is within the bills of mortality, and not required to be of particularly great solidity, it will be sufficient to describe that the thicknesses of the walls, their heights above the roofs, &c., shall be conformable to the regulations contained in the Building Act of the 14th Geo. III. c. 78.

When the work is to appear without a stone or plaster facing, there must be described *rubbed* and *guaged arches* for all the external openings that will be seen in the principal fronts, of 9 or 14 inches in depth (or more according to their span), accurately cut, and set closely in front, in back, and on their sofites. To the other openings the arches are to be described plain arches, closely set; those which appear externally to be tuck-pointed on their outside faces. Over all lintels, too, in external walls, the specification should provide uncut accurately formed arches.

When *fascias* are formed of brick, they must be described with their projections, as also all cornices formed by the arrangements of bricks, whereof the heads may be required to show as modillions; but a drawing should, for the latter, always appear on the drawing or specification.

When the shafts of chimneys are carried up above the roof, out of the common way, they must be referred to drawings; otherwise what relates to them and their flues is merely described as follows: — *Turn, parget,* and *core* the chimney flues, and finish the shafts with salient courses 6 inches in height, with *double plaintile creesing* thereto, and for each flue provide and fix a large-sized chimney mould; the upper courses of the shafts above the creesing to be laid in Parker's cement. In most cases, now, the flues are covered with square chimney moulds, cast of Parker's cement, and may be described as plain or moulded, and otherwise ornamented.

When parapets are not to be coped with stone or cement, they must be described as finished with double plaintile creesing, and a brick on edge thereover, all laid in Parker's cement.

Generally, where weather is to be provided against in upper courses and elsewhere, the laying in Parker's cement must be described.

Turn *trimmers* of 4-inch brickwork to all the fire-places for receiving the hearths throughout the building, except where the hearths lie on ground in basement stories.

Where there are basement stories, or the story is on the ground. Describe piers 9 inches square, or continued walls 9 inches thick, to carry the sleepers whereon the joists of the floor or the courses of paving stone are to lie; in either case the cavity is to be filled, for at least 9 inches in height, with dry lime core.

Bed in mortar all bond timber, wall or other plates, lintels, wood, bricks, templets, stone, or other work connected with the brickwork. All the door and window frames to be bedded in and pointed round with lime and hair mortar. Execute all requisite beam fitting.

When the building is faced with stone, or stone dressings are used; to the above must be added — back up and fill in solid with brickwork all the stone work and iron work that is set in the brickwork.

If cornices, fascias, &c. are to be run in Parker's cement, or other sort of plaster, the instruction is — Prepare and fix brickwork, and such Yorkshire stone slabs and other materials as may be necessary for forming the several external cornices, pediments, strings, sills, and dressings to openings, in Parker's cement, or other cement, as the case may be, as shown on the drawings.

Turn arches in cement (if wanted) for carrying entrance or other steps. Provide all brickwork for stone steps. Turn vaults of brickwork (describe thickness not less than 9 inches) over the intended cellars, according to the drawing, and properly cut all groins of intersections. The spandrels to be filled in with solid brickwork up to the level of the internal crown of the vaulting, the whole grouted with liquid mortar. When the centering is struck, the sofites of the vaultings are to be evenly and fairly cleaned off, and pointed.

Construct round the building a dry drain, as shown on the drawings, the top of the wall thereof to be level with the sections of the ground. Ram down the ground at the back thereof as the work is carried up, and provide such stone stays from the building as may be necessary for maintaining such wall in its place.

To execute proper barrel drains for draining the premises, as shown on the plans, to fall into a main sewer, or cesspool, as the case may be. The principal drains to be 1 ft. 6 in. and the smaller ones 12 inch barrelled drains, with half-brick rims, and the lower half of each drain composed with pure Parker's cement. At the foot of all rain-water, soil, and waste pipes, proper brick funnels are to be formed to lead down to the drain, the same to be constructed in Parker's cement. From all sink-stones funnels and drains to be formed to lead to the principal drains. N. B. We have here described the sizes of drains as for a moderate-sized mansion. We might say that 30 inches is the maximum diameter likely to be required for a large building, and none should be made less than 9 inches wide with half-brick sides, three courses high, arched, and paved.

When a portico is designed, provide and execute walls for carrying the columns of portico, as shown on the plan, all piers or cross walls for receiving the landings, and brickwork to receive the steps. If the portico be of large size, describe discharging arches above the architrave in the space over intercolumniations, and from return columns to main walls. If a pediment, back up with brickwork behind the tympanum of pediment quite up to under side of raking cornice of pediment.

Wells, when above 6 feet in diameter, should be described to be steaned in a thickness of one brick, and when less than that size, in half a brick.

When water cannot be carried off to a public sewer or running stream, *cesspools* must be formed to receive it, and allow, if possible, its absorption by the earth. They are usually 3 feet 6 inches to 5 feet clear diameter, and are to be described as circular on plan, steaned round with hard stocks, in half a brick thick, laid dry till within 18 inches of the top, which 18 inches are to be laid in Parker's cement. If there be privies or water-closets far apart, each must be provided with a cesspool. Cesspools are sometimes domed over in brickwork, with a circular stone let into the eye or opening at the top of the dome; or they may be described to be covered with Yorkshire stone.

If any fence walls are required, their footings, thicknesses, heights, and lengths are to be mentioned, and of what bricks they are to be built. If any thing peculiar in their form, a section and elevation should be given.

Bricknogged partitions, which in practice ought, if possible, to be avoided, and are only to be justified where room is an object, are described as with bricks laid flat, or on edge, filled in between the quarters, ties, &c. of the partition.

Strong closets for plate or deeds require merely description of thickness of walls and brick arch, and usually 4-inch walls brought up for holding the requisite number of shelves. The same of wine cellars, whose bin walls must be mentioned.

Paving with bricks is described to be either of stocks, paving bricks, malm paviors, or clinkers, which may be laid flat or on edge in sand, mortar, or cement, and either straight-coursed or herring-bone.

Paving with tiles is usually in mortar; the tiles may be either 10 or 12 inches square.

All splays, ramps, and *chases* to be cut where wanted; the two former to be rubbed where necessary, and the latter to be pargetted

Brick ovens (one 10 feet wide and 8 feet 6 inches deep will bake twelve bushels of bread, and one 8 feet wide and 7 feet deep will bake eight bushels, and so in proportion) are to be constructed with Welsh lumps or fire bricks for fire-place, domed over, and hooped with iron hoops. The bricklayer is to provide the bars, plate door, bar to the archway of door, and other ironwork, and to carry up a proper flue from the fire.

Iron ovens. The bricklayer is to set in proper brickwork an iron oven capable of baking two bushels of bread.

Coppers and stewing stoves to be set neatly in brickwork, the latter in guaged brickwork with tile top, and proper flues carried up therefrom.

Columns to porticoes or fronts which are to be coated with cement must be described of such diameters as the drawings for finishing require, with entablature, &c., as the case may be, carried up in Parker's cement.

In describing stables, besides what may be applicable from the foregoing directions, two *air-flues* are to be constructed to each stall and loose box, 9 inches square, and

Bricklayer.

carried up over the racks within the thickness of the brickwork, communicating at their tops with the external air by curved tops to secure them from the penetration of the rain. *Dung-pit walls*, whose dimensions depend on the size of the stables. *Lime white* walls of stables.

If roofs are covered with tiles, either pan or plain. The description for the former will be either laid dry, or bedded in lime and hair, or pointed outside or inside, or on both sides; or if glazed pantiling, to be so described, laid to a 10-inch guage on stout fir laths, with hip, ridge, and valley tiles, filleting cutting to splays, beam filling, painted T nails, hip hooks, &c. *Plain tiling* is described as laid to a close guage on heart of oak double laths, with all the plaintiles pegged. The hip and ridge tiles to be set in Parker's cement, with T nails dipped in melted hot pitch in all the joints. Strong, similarly pitched, wrought iron hip hooks. Filletings of Parker's cement, with strong cast iron nails for forming a key driven into the walls or other brickwork at intervals, close enough to secure the same.

In cases of underpinning the bricklayer is to cut all holes for the needles, and to remove the old work, and to bring up the work in Parker's cement on concrete foundation; and, finally, drive the cast iron wedges for bringing the work to a solid bearing.

Where inverted arches are used in foundations they must be shown on the drawings.

Provide, according to the extent of the job, a certain number of rods of brickwork for such extras as may be ordered by the architect; and if the whole or any part thereof should not be wanted, a deduction to be made on settling the accounts for so much thereof as shall not have been used, at a price per rod to be named.

To build all the walls level, except otherwise directed; to be answerable for all damage that may occur to the work, by settlements or otherwise, during the time of building, and to make good the same as the architect shall direct; and, further, to perform all such jobbing work as shall be necessary for completely finishing the building. To provide good sound and sufficient scaffolding, which is to remain for the use of the mason, carpenter, and other artificers that may have occasion to use the same.

To pay the proper fees to the district, sewer, and paving surveyors, and to give the necessary notices and obtain the proper licences in their departments for executing the works. This only applies in the bills of mortality, where there are such officers.

2283. Slater. To cover the roofs with the best strong Westmoreland, Tavistock, Welsh rag, imperial, queen, duchess, countess, ladies, or double slating, (as the architect may think most appropriate, each being named in the order of the value and quality,) securely fixed with best strong copper nails. Every part to be properly bonded, especially at the eaves and heading courses thereof, with slates cut to keep the bond uniform. No slates to be laid lengthwise.

Fillets against the brickwork, where requisite, of Parker's cement; such fillets to be formed with nails driven at proper intervals to form a hold for the cement (where lead step flashings are intended the fillets need not be described). Fillets of brick or stone may be built up with the wall, level or raking; and if they should be preferred by the architect, they must be described in the bricklayer's or mason's works.

All the slating is to be rendered up perfect on completing the building, and all jobbing work to be performed that may become necessary as the work is carried on.

If the slating is required to be rendered as air-tight as possible, it must be described to be pointed on the inside with stone lime mortar, with a proper quantity of hair therein; but the pointing of either slates or tiles, from the constant expansion and contraction arising from heat and cold, soon falls out and becomes useless. Slater to be answerable twelve months for his work.

If slate skirtings and cisterns are intended about the building, they must be particularly described.

2284. Mason. The stone to be used in a building generally depends of course on the place where it is to be built, unless, without regard to expense, the employer determines on the use of any particular sort; in which case the account of the different quarries of the provinces, given in Chap. II. Section II. of this Book, will furnish the architect with the means of describing the best of its sort. For the choice, therefore, where it is left to the architect to decide, we must refer him to that account. In the neighbourhood of London that from the island of Portland is most used. Granite is chiefly used where great strains and pressures occur, or where wear and tear and the action of the weather indicate its employment.

Having described the sort of stone selected to be of the best quality, free from all vents, shakes, &c., the next direction is, that it shall be throughout laid in the direction of its natural bed in the quarry; and if the whole building is of stone, many of the following particulars will be unnecessary,—which of them will immediately speak for themselves. Where the building is only faced with stone, the specification will run as follows:—The . . . fronts (describing them) are to be faced with Portland (or other, as the case may be) stone, ashlaring in courses to fall in with the courses of brickwork, carried up after the manner of Flemish bond. The stretchers of such ashlaring being 4½ inches deep and the headers 9 inches, with bond stones running through the whole thickness of the wall in the proportion of $\frac{1}{16}$ of the face, to be introduced where the piers allow. No quoins to show a thickness of less than 12 inches. The whole to be cramped with iron cramps to the satisfaction of the architect, the mason finding the same, and properly running them with lead.

In cases where the building is of brick with stone dressings, the specification will run thus:—To provide and set a Portland stone (or other stone or granite) plinth all round (or part, as the case may be) the building, . . . feet . . . inches high and 8½ thick, in stones not less than 3 feet in length, the vertical joints to be cramped with T cramps not less than 12 inches long. Describe whether joints are to be close or channelled, and whether ashlar is to be rusticked (rockworked). To provide and fix at the angles of the building, as shown upon the drawings, solid quoins of Portland (or other, as the case may be) stone [here describe whether close, champosed, or channelled joints, and whether rusticked (rockworked)] of the length and height shown.

To provide and fix, as shown, string courses, scantling . . . . inches by . . . . inches, throated and bevelled on the upper face, and the joints plugged with lead.

To provide and fix, as shown on the drawings, a cornice and blocking course, scantling . . . by . . . , moulded according to the drawings, the bed to be such that the weight of each block of stone in the projecting part shall not be equal to that on the bed by one fourth of its cubic contents. The same to be executed according to the drawings; to have proper sunk water joints, and to be channelled and plugged with lead at all the joints.

Blocking course, as shown on the drawings, . . . inches high, . . . thick on the bed, and . . . on the top, plugged with lead at all the joints, with solid block at the quoins returned at least 24 inches.

Balustrades (if any) to be provided of the heights and sizes shown on the drawings and section thereof. The balusters to be wrought out of stone, allowing at least 1 inch of joggle at their ends into the plinth and impost. All the vertical joints to be well plugged with lead; the impost to be cramped with cast iron (or bell metal), and the whole to be securely fixed. The half balusters to be worked out of the same block of stone as their adjoining pedestal.

Columns and pilasters (if any), with pedestals, capitals, bases, plinths, &c., and entablature, to be provided and fixed as shown on the drawings. The columns and pilasters not to be in courses of more than . . . blocks of stone. The architraves to be joggled from those resting on the columns or pilasters themselves, and these as well as the frieze and cornice to break joint over the architrave. The architraves, if blocks of stone can be supplied large enough, to be in one block from centre to centre of column, with return architraves in like manner. The whole of the entablature (as well as the pediment, if any) to be executed with all requisite joggles and cramps; and if a pediment be projected, the apex to be in one stone, as shall be approved by the architect. The pilasters (if any) to be bonded not less than . . . inches into the wall, against which they are placed in every other course. The sofites of the portico to be, as shown on the plan and sections, formed into panels and ornamented. Provide and let into the top of the architrave good and sufficient chain bars, with stubs on the under side for letting into every stone composing the architrave.

If the portico be very large, it is not necessary to make the frieze solid, but concealed arches should be turned in the space from column to column to support the superincumbent weight of the cornice and pediment. If the columns are fluted, it must be mentioned.

When a pediment, the tympanum may be described to be faced with ashlaring.

To construct and fix dressings and sills to the external windows and doors, as shown on the drawings, with all such throated, sunk, moulded, carved, rebated, and other works as may be necessary.

If a portico is shown, to provide and fix of solid . . . stone . . . steps round the portico scantling . . . by . . . , properly back-jointed and worked all over; and within the portico to provide and fix a complete landing of stone, at least 4 inches thick (or less, if a small portico), in slabs, as shown. The joints of the steps and landings are to be joggled and run with lead.

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All ornaments, carving, enrichment of capitals, of columns and pilasters, and of such as may be shown in the entablature, is to be executed in an artist-like good style. Models from the working drawings are to be made at the contractor's expense, and the whole to be executed to the satisfaction of the architect.

The order may be described if the working drawings are not sufficiently made out.

Provide and fix plinths and base mouldings to the portico, as shown on the drawings, to be worked out of (describe stone) . . . stone of . . . by . . . scantling.

Finish the chimney shafts with mouldings as shown in the drawings, or with sunk moulded and throated copings, . . . inches wide and . . . inches thick.

To describe sills generally, take the following: —

Sills to . . . windows of Portland stone, 9½ by 6 inches.

Sills to . . . windows moulded and of Portland stone, 14 by 8 inches.

Sills to . . . windows of Aberdeen granite, finely tooled, scantling 14 inches by 9 inches.

Sills to . . . windows of Portland stone, 9 by 5 inches.

All window sills are to be properly sunk, weathered, and throated, and at each end to be 4 inches longer than the opening.

To provide and lay to all the walls Yorkshire stone 3 inches thick and 4 inches on each side wider than the several lowest footings, in slabs of one length across the width of the footing.

If balconies to a house, describe thus: — A balcony landing of Portland stone . . . . inches thick, moulded on the edges and the pieces joggled together, and run with lead, to be provided with holes cut therein for the iron railing. The said balcony is to be tailed into the wall, and securely pinned up.

Steps to doorways must be described as to scantlings. All external steps should be weathered.

Where story posts are used in a front, it is well to place along the front two pieces of parallel square Aberdeen or other good granite curb scantling, 12 inches by 9 inches, cut out to receive the bases of the columns and story posts.

For a back staircase, carry up and construct a staircase from the basement to the principal floor, with solid Yorkshire quarry steps 13 inches wide and 6½ inches high, properly back-jointed and pinned into the brickwork; cut holes for the iron balustres. N. B. This sort of staircase of Portland will serve also for back stairs of upper flights. That from the basement may also be made of granite street curb, 12 by 7 or 8 inches. A staircase may, for cheapness, be made of Yorkshire stone paving 3 inches thick, wrought with fair tooled edges, and securely pinned into the brickwork.

Principal stairs to be of Portland stone (as may be), to extend from principal to . . . floor, with steps and square (or semicircular, as may be) landings, entirely of solid stone, tailed 9 inches into the brickwork, with moulded nosings and returned nosings, and also at the back. The sofites to be moulded to the shapes of the ends of the steps. The landings to be 6 inches thick, with moulded nosings and joggled joints, run with lead, to be inserted at least 4 inches in the walls, but such as tail into the walls, as steps, must go at least 9 inches into the walls.

When the under sides of the steps of the geometrical staircase are not moulded, the nosings are returned so as to fall beyond the upright line of the succeeding tread; in this case the sofite or string is plain wrought.

Pave the entrance hall and principal staircase, together with (any apartments wished) with the best . . . marble, and border according to the pattern drawn.

The back staircase (and such other parts as require it) is to be paved with Portland stone 2 inches thick, laid in squares, and with a border 8 inches square.

Dairy, if any, to be paved with . . . . stone, in regular courses . . . . inches thick. Provide a shelf or dresser round the said dairy of veined marble 1 inch thick, and a skirting round it 6 inches high. The dresser to go into the wall 1 inch, and to be supported on veined marble piers 4 inches square.

Pave the scullery, larder, pantry, passages, lobbies (and such other places as may require mention), with rubbed Yorkshire stone 2½ inches thick, laid in regular courses with close rubbed joints.

Pave the bottom of the air drain with Yorkshire paving.

Yards may be paved with 2½-inch Yorkshire paving, or such other as the place affords, as in common use. The same to basement stories.

To fit up the wine cellar with bins, as per drawing, with 3-inch Yorkshire stone shelves (some prefer slate), fairly tooled, and set in Parker's cement.

To provide and fix a warm bath of veined marble; render waterproof by being properly set in Dutch tarras, and plugged and cramped with copper at the joints, with all requisite finishing. A marble step round two sides of the bath. Cut all holes necessary for laying on the water. A bath may be similarly made of slate, which is of course much cheaper.

Where iron girders are used, describe .... pieces of granite street curb, each .... feet long, to receive the ends of the cast iron girders.

Where chimneys project without support from below, corbels must be described proportioned to the weight they have to carry. The best corbel, however, is the gradual projection of the work by inverted steps, which, if there be height to hide them, should always be the mode of execution.

Cellar doorways should have in each of them three pieces of Portland or other such stone, 18 inches wide, 18 inches long, and 9 inches high, cut out to receive the hinges and rim of the lock.

All fire-places should have back hearths of 2½-inch rubbed Yorkshire stone.

The commonest chimney-pieces that can be described are of 1½-inch Portland, jambs, mantels, and shelves, 6 inches wide; slabs of 2-inch Portland stone, 20 inches wide.

For butler's and housekeeper's rooms drawings are usually given. They may be of Portland stone slabs, 2 inches thick, 4 feet long, and 1 foot 8 inches wide.

For a kitchen chimney, describe jambs and mantle of 2-inch Portland stone, 10 (or 12) inches wide, with a slab of 2½-inch rubbed Yorkshire stone. The mantel to be in one piece.

For the several rooms where marble chimney-pieces are to be placed, chimney-pieces are described to be provided of a given value, varying in the less important to the best apartments, from eight or ten up to 100 guineas or more in value, of such marble as the employer may select: but if the working drawings have been fully prepared, this is a matter which need not be left in uncertainty. It must always be provided in the specification that the slabs are included, and that the price is or is not (as the case may be) to include the carriage and fixing.

Sinks of Portland or other stones, 7 inches thick (describing the size required), to be provided and fixed as shown in the drawings, with holes cut for the grating and socket pipe, and fixed with all requisite bearers complete.

Sink stones to be provided where shown on the plan. The joints generally are to be where exhibited on the drawings, and the work is to be left perfectly cleaned off, all necessary joggles, joints, rebates, moulded, sunk, weathered and throated works, grooves, chases, holes, back joints, and fair edges, that may be necessary in any part of the work, and all jobbing, though not particularly mentioned under the several heads, is to be performed that may be requisite for the execution of the building, and all the work is to be well cleaned off before delivering it up. The whole of the work is to be warranted perfect, and any damage that may occur to it by reason of frost or settlement within two years after the completion of the building is to be repaired, under the architect's direction, at the sole expense of the contractor.

All mortar is to be of the same quality as that described in the bricklayer's work.

The contractor is to provide lead to run the cramps and joints.

In works within the bills of mortality, the contractor is to pay the expense, under the commissioners of sewers or paving, as the case may be, of making good the street paving to the areas, plinths, and steps abutting thereon.

To provide and fix under the contract .... cubic feet of .... stone, including plain work and setting thereto, also .... superficial feet of 2½-inch Yorkshire paving, laid in regular courses; and in case the whole or any part of either or both should not be wanted, the quantity not used or directed shall be deducted from the amount of the consideration of the contract after the rate of .... per foot of cubic stone and .... per foot superficial for the Yorkshire paving, including the workmanship and fixing thereof.

In stables, granite should be provided to receive the heel-posts if cast-iron be not employed, and at the piers of gates, hinge and spur stones, the latter, of granite, if to be had, should be described. The caps and bars of the last can be described only with reference to the drawings of them.

The paving of stables and their courts is described thus: Prepare the ground for paving (stating where) with good and sufficient hard materials, and pave it with Aberdeen granite paving, properly dressed and sorted, 8 inches deep and 5 inches wide at the top and bottom thereof. The whole to be laid with good currents upon a layer 4 inches at least in thickness of good rough gravel, the joints of the surface to be run with stone lime and river sand grouting. It is to be well rammed, and the contractor is to relay, at his own expense, all such parts as may sink within eighteen months of the work being completed.

Where the work is within the bills of mortality, or within a town, specify that a sufficient hoarding is to be erected for enclosing the premises during the execution of the

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works, which is to be removed and carried away when they are complete. So, also, all shoring is to be provided, if the works be alterations, or the adjoining buildings may be injured by carrying them into effect. The shoring is to be performed in a safe, scientific, and workmanlike manner, of the fronts, floors, or otherwise, as the case may be.

2285. **Carpenter and Joiner.** Where the extent of the works requires a clerk of the works: a direction must be given to provide, erect, and maintain, during their performance, a temporary office for the clerk of the works, with all appurtenances complete, with stool, table, and all other requisite furniture.

All materials requisite for completion of the buildings according to the drawings are to be provided by the contractor. The oak is to be of English growth; the timber not specified of oak is to be of the best Dantzic, Riga, or Memel yellow fir. No American, Swedish, or Scotch fir to be used in any part of the building. All the floors and joiner's work are, except where otherwise directed, to be of the best Christiana deals. The timbers and deals are to be cut square, entirely free from sapwood, shakes, large knots, and all other defects. If any part or parts of the joiner's work should shrink or fly within eighteen months from the finishing and fixing the same, the contractor is to take down, refix, and make good the same, together with all works that may be affected thereby, at his own expense.

No joists, rafters, or quarters are in any case, unless particularly so directed, to be more than 12 inches clear distance from one another.

To provide and fix, ease, and strike all centering and turning pieces for the vaults, arches, trimmers, and other works. Provide all temporary shores that may be necessary. Fix all iron-work of every description. Provide and fix all necessary templets, linings, blocks, stops, casings, beads, springing fillets, angle staffs, grounds, linings, backings, furrings, cappings, and other finishings incident to carpenters' and joiners' works, together with all necessary grooving, rebating, framing, tonguing, housing, beading, mitring, framing, and other workmanship necessary for completing the works.

To provide good and secure casing for all the stone dressings, to protect the same from injury during the execution of the works; and any accident arising from neglect in this respect is to be made good at the expense of the carpenter.

Bond timber. One tier is generally enough for basement story.
Two tiers in the other floors, unless very lofty.
One tier in the upper story.

4 inches by 2½ inches all around the walls, except where intercepted by the chimneys, to be lapped together, where joints occur, at least 6 inches, and to be properly spiked together. Party walls may be bonded with iron hooping, if thought proper, for a greater security against fire.

To find and fix all wood bricks for fixing the finishings to.

Provide and fix all lintels, and filling in lintels that may be necessary to the several openings: each to be 4 inches high, of the width of the brick work, and 16 inches longer than the opening.

Two small lintels will do if the width of the sofite be considerable, and arches as directed in the bricklayer's work be turned.

For ground or rather basement floors, walls are brought up for receiving oak sleepers, 5 by 3 inches; on which fir joists 4½ by 2½ are generally the scantlings employed.

For other floors. Wall plates 6 by 4 are described.

Girders - -
Joists of all descriptions, according to the kind of floor -
Trimmers and trimming joists

} All which, with their requisite scantlings, will be found in Practical Carpentry. (2013, *et seq.*)

Cradling to the girders and such parts as may be necessary to form panels and coffers on the under side for the ceiling, if such be practised.

Where it is necessary to truss the girders, that must be stated.

Cock down all girders on the wall plates. Pin bridging joists to binders with ¾-inch oak pins.

For roofs, wall plates should be at least 6 inches by 6 inches.

For the different timbers of the several sorts of roofs, the reader will refer to the section on Practical Carpentry, where they are described, and scantlings given of works that have been executed. (2027, *et seq.*) Ceiling joists also to be described.

To what is there found, we may add, that hips and ridges rounded for lead ought to be 10 by 2.

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Where close boarding is used, it should not be less than ¾ to an inch thick. If battens for slating, they should be 2½ inches wide; the first should be nailed with eightpenny nails. Provide lear boards.

We prefer, on many accounts, and, indeed, ourselves usually adopt, the Italian method of laying the rafters horizontally as so many purlines. For the boarding thus lying lengthwise towards the gable, any wet that may find its way on to it from defective slates or lead, is not apt to lodge against and rot the edges.

Flats are described with wall plates usually 6 by 6. Trimmers and trimming joists against chimneys, and where skylights occur; and 1¼-inch yellow deal boarding, listed, free from sapwood, laid with a current of 1½-inch to 10 feet lineal, with 2½ drips to heading joints, of lead rolls to longitudinal joints, and inch yellow deal risers not less than 4 inches wide next the gutter

Gutters to the roof or roofs are to be as shown on the plan, with inch yellow deal bottoms on strong fir bearers, and laid with a current of 1½ inches to every 10 feet; 2½ rebated drips, and at the sides to have ¾-inch deal lear boards, 9 inches wide. Gutter boards are rarely more than 1¼ inch thick.

Gutter plates, if any, to be described, but they should never be used without support from below.

Trim for trap doors, if any, leading to the roof, and provide and fix dormers with all necessary framing.

Cheeks, doors, beaded stops and linings, and ironmongery. Boarding for slating or lead to top and cheeks, as the case may be.

Dormers may be similarly described for windows in the roof.

Quartered partitions, where shown on the plan, with heads and sills 4 inches by 4 inches. Ties above the doors 4 inches by 5 inches. Posts 4 inches by 3½ inches. Braces or struts 3 inches square. Quarters 4 inches by 2 inches, and three tiers of interties, 1 inch by 2½ inches. In cases where partitions are to be trussed for carrying either their own or some additional weight, reference must be made to drawings.

To put to . . . . floors (or to the whole if desired) *sounding boarding* of ¾-inch deal, chopped and fixed upon fillets to receive the pugging.

All external walls should be described to be battened. The thickness of the battens is usually from ¾-inch to 1¼-inch, their widths 2¼ inches, and they are placed from 7 to 12 inches apart. If no bond timber to nail them to, plugs must be let into the walls.

Bracketing and cradling is usually, for cornices, cones, &c., 1¼ inch thick; for entablatures, circular sofites, and waggon-headed ceilings, 1½ to 2 inches thick.

All bearers to be fixed and provided as shall be necessary.

Weather boarding of the best sort is described as 3-inch yellow deal, wrought, or wrought and beaded.

Luffer boarding ought to be of 1-inch deal, wrought two sides and splayed.

Warehouse posts must be described with their relation to the weight they are to carry (see Mechanical Carpentry, 1600, *et seq.*), the caps to them should be long, so that they may not press into the girders, and, if practicable, iron dowels should pass through the girders to catch the bases of the posts in the floor above.

In ordinary cases fir story are about 9 inches square. Oak caps 3 feet long, with splayed ends 9 by 6. Flools are usually rough, not less than 1½-inch deal rebated.

Water trunks are made of sizes from 4 to 6 inches or more square, of ¾-inch to 1¼-inch deal. They are always to be described as pitched and fixed complete, with hopper heads and shoes, wall hooks, holdfasts, &c.

Park paling is of the following varieties, and must be described accordingly: —

4-feet oak cleft pales, 2 arris rails and oak posts.
5-feet oak cleft pales, 2 arris rails and oak posts.
6-feet oak cleft pales, 3 arris rails and oak posts.

If there is to be an oak plank at the bottom, and oak capping at top, they must be specially mentioned.

To provide and fix . . . cubic feet of Baltic yellow fir timber, with all labour thereto, beyond the quantity necessary for the work herein described, to be used in such additional works as may be directed by the architect; and if the whole or any part thereof should not be ordered, the same shall be deducted from the amount of the consideration of the contract, after the rate of . . . per foot cube. All additional fir, if any should be ordered, is to be taken at the like price of . . . per foot cube.

The varieties of *floors* are as follow, each set of thicknesses being enumerated in the order of their increasing value. Batten floors are for better rooms.

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¾-inch *white* deal, rough, with edges shot.
¾-inch *white* deal, wrought, and laid folding.
¾-inch *yellow* deal, rough, with edges shot.
¾-inch *yellow* deal, wrought, and laid folding.
¾-inch *white* deal batten floor, wrought, and laid folding.
¾-inch *yellow* deal batten floor, wrought, and laid folding.
1-inch *white* deal, rough edges shot.
1-inch *white* deal, wrought, and laid folding.
1-inch *white* deal, wrought, and laid straight, joint and splayed headings.
1-inch *yellow* deal, rough edges shot.
1-inch *yellow* deal, wrought, and laid folding.
1-inch *yellow* deal, wrought, and laid straight, joint and splayed headings.
1-inch *white* deal batten floor, wrought, and laid folding.
1-inch *white* deal batten floor, wrought, and laid straight, joint and splayed headings.
1-inch *yellow* deal batten floor, wrought, and laid folding.
1-inch *yellow* deal batten floor, wrought, and laid straight, joint and splayed headings.
1¼-inch *white* deal, rough edges shot.
1¼-inch *white* deal, wrought, and laid folding.
1¼-inch *white* deal, wrought, straight joint, and splayed headings.
1¼-inch *yellow* deal, rough edges shot.
1¼-inch *yellow* deal, wrought, and laid folding.
1¼-inch *yellow* deal, wrought, straight joint, and splayed headings.
1¼-inch *white* deal batten floor, straight joint, and splayed headings.
1¼-inch *white* deal batten floor, straight joint edge nailed, and splayed headings.
1¼-inch *yellow* deal batten floor, straight joint, and splayed headings.
1¼-inch *yellow* deal batten floor, straight joint, edge nailed, and tongued headings.
1¼-inch *white* deal batten floor, edge nailed, and tongued headings.
1¼-inch *yellow* deal batten floor, edge nailed, and tongued headings.
1¼-inch *yellow* deal batten floor, dowelled with oak dowels, with mitred and glued borders.
1¼-inch *yellow* deal, clean batten floor, dowelled with oak dowels, with mitred and glued borders.

Warehouse floors are of
1¼-inch *yellow* deal, rough edges shot.
1¼-inch *yellow* deal, wrought, and laid folding.
1¼-inch *yellow* deal, wrought, and straight joint, and splayed headings
2-inch *yellow* deal, rough edges shot
2-inch *yellow* deal, wrought, and laid folding.
2-inch *yellow* deal, wrought, and laid straight, joint and splayed headings.
All these last may be ploughed, rebated, and feather-tongued.

The floors of inlaid or *parquetry* work must form, when to be provided, special subjects of specification; they must be described according to drawings, on which are to be marked the different woods to be used in their formation.

The varieties of *skirtings* are classed as under, beginning with the commonest sort: —
½-inch deal square skirting.
¾-inch deal square skirting.
¾-inch deal torus skirting.
1-inch deal square skirting.
1-inch deal square skirting, rebated, and backed plinth, with fillet nailed to floor.
1-inch deal torus skirting.
1¼-inch deal square skirting.
1¼-inch deal torus skirting.
1¼-inch deal torus skirting, rebated, and backed plinth, with fillet nailed to floor.

If any of these, as to stairs for instance, are raking, and to be scribed to steps, they must be so described, and so if any of them are to be ramped, and similarly if they are to be scribed to moulded nosings, as also if they be circular on the plan.

Dados in their varieties are as follow, premising that they are nailed to grounds which should be mentioned.
¾-inch deal keyed.
1-inch deal keyed.
1¼-inch deal keyed.
1¼-inch deal keyed, ploughed, and tongued.
1¼-inch deal keyed, feather-tongued.

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Scribed to steps, circular on plan, and wreathed, or ramped: those matters must be mentioned.

Of *wainscotting* with fascia and skirting, the different kinds are subjoined in the order of their quality.

1-inch deal, square framed
1-inch deal, square framed dwarf
1¼-inch deal, square framed
1¼-inch deal, square framed, dwarf
1¼-inch deal, bead butt or moulded
1½-inch deal, bead butt
1½-inch deal, bead flush

The number of panels high to be specified.

When any of these are raking, or to have a beaded or moulded capping, or both or either, such must be specified.

Partitions of deal for the division of rooms are only used in taverns and the like; but where they are wanted, as for a mere separation in servants' rooms, they may be employed. Their varieties are —

1-inch deal board, and braced with ½-inch panels.
1¼-inch deal, braced with ¾-inch panels.
1½-inch deal, rough, and ledged edges shot.

These are scarcely to be employed.

1½-inch deal, wrought both sides, and ploughed.
1½-inch deal, wrought both sides, tongued, and beaded.
1¼-inch, square framed.
1½-inch, square framed.
1½-inch, bead butt, moulded, and square.
1½-inch, bead flush and square.
1½-inch, moulded on both sides.
2-inch, square framed.
2-inch, bead butt or moulded and square.
2-inch, bead flush and square.
2-inch, moulded on both sides.
2-inch, moulded and bead flush.
2-inch, bead flush and bead butt.
2-inch, bead flush on both sides.

These, as well as any preceding and following parts of a specification, will, of course, have reference to what is wanted in the design which it is the architect's object to describe in such specification.

Grounds. — We have mentioned grounds generally (2166.); but it may be as well here to insert their several sorts: for instance, —

Those of ¾-inch deal, of 1-inch deal, of 1¼-inch deal, of 1½-inch deal, and whether circular; also 1-inch, 1¼-inch, and 1½-inch skeleton grounds, which it is, perhaps, for security against extras, as well as repeat.

Door cases are usually employed on basement stories, and should be of oak, though fir is constantly used for them. They fit into the brickwork, and are usually about *5* by *5* inches, and they should be tenoned (the tenon being well pitched or set in white lead) into the stone step, on which they ought to be placed; for the sill, into which it is the practice to place them, soon rots, however good the material.

Door linings and their sofites. — These are either plain or framed, the former being of the commoner sort, and the latter for better work and places. They may be enumerated as follow: —

1-inch deal, single rebated.
1-inch deal, double rebated (that is, so that the door may hang on either side).
1¼-inch deal, single rebated.
1¼-inch deal, double rebated.
1½-inch deal, single rebated.
1½-inch deal, double rebated.

Either of the foregoing, if to be beaded on the edge, must be so described. Of framed linings and sofites for doors there are —

1¼-inch, square framed in one panel and double rebated.
1¼-inch, square framed in one panel and double rebated, bead butt or moulded.
1¼-inch, square framed in one panel and double rebated, bead flush.
1½-inch, square framed in one panel and double rebated.
1½-inch, square framed in one panel and double rebated, bead butt, or moulded.
1½-inch, square framed in one panel and double rebated, bead flush.

If the panels in the linings are to be raised, to correspond with panels of doors, they must be so described.

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Framed back linings are as follow: —

1-inch deal, two panel square.
1-inch deal, two panel square, bead butt.
1-inch deal, three panel square.
1-inch deal, three panel square, bead butt.
1-inch deal, four panel square.
1-inch deal, four panel square, bead butt.

If there be more than four panels, or they are splayed on the plan, or if bead flush, or of a greater thickness, they must be so specified.

Backs, *elbows*, and *sofites* to windows are described as —

1-inch deal, keyed.
1-inch deal, keyed, framed square.
1¼-inch deal, framed square.
1¼-inch deal, framed square, moulded, or bead butt.
1¼-inch deal, framed square, bead flush.
1¼-inch deal, square framed sofite, with one edge circular. } Applicable to bay windows.
1¼-inch deal, square framed sofite, with two edges circular. }
1¼-inch deal, square framed sofite, moulded, or bead butt.
1½-inch deal, framed square.
1½-inch deal, framed square, moulded, or bead butt.
1½-inch deal, framed square, moulded, or bead flush.

If any of these are splayed, fancy moulded, and with cappings, when also they are circular on the plan, they must be so particularly specified, inasmuch as the price is thereby enhanced.

Boxings for shutters are of the following varieties: —

1-inch deal, splayed boxings.
1-inch deal, proper boxings.
1¼-inch deal, splayed boxings.
1¼-inch deal, proper boxings.
1¼-inch deal, boxings with circular head.
1-inch deal, boxings for sliding shutters, with pulley pieces, beads, fillets, and grooves, complete.
1¼-inch deal, boxings for sliding shutters, with pulley pieces, beads, fillets, and grooves, complete.

These, if to be double hung, must be so described.

Window shutters. — As in the foregoing parts of a specification, we shall proceed from the common to the better sorts.

¾-inch deal, ledged or clamped.
¾-inch deal, ledged, or clamped, in two heights.
1-inch deal, clamped.
1-inch deal, clamped in two heights.
1-inch deal, clamped in two heights, one panel, bead butt, and square.
1-inch deal, clamped in two heights, one panel, bead flush, and square.
1-inch deal, clamped in two heights, one panel, bead flush, and bead butt.
1¼-inch deal, two panels square.
1¼-inch deal, two panels square, in two heights.
1¼-inch deal, two panels square, in two heights, moulded, or bead butt, and square.
1¼-inch deal, two panels square, in two heights, bead flush, and square.
1¼-inch deal, two panels square, in two heights, bead flush, and bead butt.

These may be described of 1½-inch deal; but the back flaps need not be more than one inch, and the additional panels in height, projecting mouldings, if any, and other variations from the general description, must be mentioned.

Sliding shutters are to be described in their varieties, as follow: —

1-inch deal, two panels square, hung with lines and weights.
1¼-inch deal, two panels square, hung with lines and weights.
1¼-inch deal, bead butt and square, hung with lines and weights.
1¼-inch deal, bead flush and square, hung with lines and weights.
1¼-inch deal, bead butt and moulded, hung with lines and weights.
1¼-inch deal, bead flush and bead butt, hung with lines and weights.

These, if of 1½-inch deal, and if more panels in height, must be so described; so also if they are circular on the plan; and if patent lines are to be used for the hanging, they must be mentioned.

Outside shutters, now rarely used, even in the provinces, except for shop fronts, must be mentioned, to make our description complete; they are of

1½-inch deal, three panels, bead butt and square.
1¼-inch deal, three panels bead flush and square.

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1¼-inch deal, three panels, bead flush and bead butt.
1¼-inch deal, three panels, bead flush on both sides.
1½-inch deal, three panels, bead butt and square.
1½-inch deal, three panels, bead flush and square.
1½-inch deal, three panels, bead flush and bead butt.

If these are circular on the plan, or contain more than three panels in height, the specification must so state.

Staircases are described as under, beginning with the commonest.

1-inch yellow deal, steps, risers, and carriages.
1¼-inch deal, steps, inch risers, and carriage.
1¼-inch deal, steps and risers glued up and blocked to close string moulded nosings, and two fir carriages.
1¼-inch deal, steps and risers mitred to cut string, and dovetailed to balusters.
1¼-inch deal, steps to winders, mitred to cut string, and dovetailed to balusters, one end circular.
1¼-inch deal, steps to winders, mitred to cut string, and dovetailed to balusters, both ends circular.

If the risers are to be tongued to the steps, if feather jointed, or if of clean deal, such must be stated in the specification.

1½-inch deal, wrought steps, risers, and strong carriage.
2-inch deal, wrought steps, risers, and strong carriage.
1¼-inch oak, treads and risers mitred to string and dovetailed with fir carriage (with solid quarter ends to steps if required), also curtailed step and riser (2187, *et seq.*), returned moulded and mitred nosings, circular, if necessary, with cut plain (and circular) brackets.

Housings to ends of steps and winders, and the same to moulded nosings and circular ends, are to be specified.

String boards to staircases to receive the ceilings of stairs (or strings as they are called), are —

1-inch deal, framed.
1-inch deal, framed, rebated, and beaded.
1¼-inch deal, framed string board.
1¼-inch deal, framed string board, sunk and beaded.
1¼-inch deal, framed string board, sunk, beaded, and moulded.
1¼-inch deal, framed string board, sunk, beaded, moulded, and mitred to risers.
1½-inch deal, wreathed outside, string glued upright, rebated, and beaded.
1½-inch deal, wreathed outside, string glued upright, rebated, beaded, and sunk.
1½-inch deal, wreathed outside, string glued upright, rebated, beaded, sunk, and moulded.

If the string is to be glued up in thicknesses, that must be specified, as also all plain or moulded circular cuttings or ramps.

1-inch deal, plain wall string.
1¼-inch deal, plain wall string.
1½-inch deal, plain wall string.
2-inch deal, plain wall string.

If moulded, to be so described.

Handrails to staircases are described as —

1¼-inch deal, plain wreathed.
1½-inch deal, plain wreathed.
2-inch deal, plain wreathed.

If moulded, state so.

Deal moulded 2½-inch handrail.
Deal moulded 2½-inch handrail, ramped (or circular where required).
Deal moulded 2½-inch handrail, wreathed and twisted.
Honduras mahogany or wainscot moulded handrail. To be described if necessary with ramps, circular and twist, or with scroll and twist to the curtail step.
Spanish mahogany handrail is also similarly described.

If grooved for balusters, circular, or sunk for iron cores, mitred and turned caps, such to be mentioned.

Balusters and newels are described —

Deal square framed newels.
Deal square framed newels, chamfered.

Single and double turnings to newels to be mentioned, as also pendent drops, when used.

Deal square bar balusters.
Deal square bar balusters, dovetailed.

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Turned balusters according to drawing, when necessary.

Planceer rounded on both edges, or moulded, as the case may be.

Fix all iron balusters and stays.

Sash frames are of great variety, whereof the following is a list: —

Deal cased frame for 1½-inch sashes, oak sunk sill with brass pulleys for single hanging.

Ditto, for double hanging.

Ditto, ditto, with circular head.

Ditto, circular on plan (and with circular head, when required).

Deal cased frames for 2-inch sashes, oak sunk sills with brass pulleys prepared for single hanging.

Ditto, prepared for double hanging.

If circular on head and plan, or either, such to be specified.

Deal-cased frames for 2-inch sashes, oak sunk sills with wainscot pulley pieces and beads, brass axle pulleys prepared to hang double.

If circular on head and plan, or either, such to be specified.

Deal cased frames for 2-inch sashes, oak sunk sills, mahogany pulley pieces and beads with brass axle pulleys, prepared to hang double.

The same description holds for 2½-inch sashes.

If, as before, circular on head and plan, or either, such to be mentioned.

Venetian frames are described as —

Deal cased frames for 1½-inch sashes, oak sunk sills, and prepared to hang single or double, as the case may be.

If circular on plan and head, or either, specify the same.

The above description for 1½-inch serves also for 2-inch and 2½-inch sashes.

If wainscot or mahogany, they must be so described.

Casement frames for French casements: —

Fir solid wrought frames for 1½-inch French casements, with oak sunk sills (plain or circular on the plan, as the case may be).

Fir solid wrought frames for 2-inch French casements and oak sunk sills (as before).

Fir solid wrought frames for 2-inch French casements and oak sunk sills (as before), with wainscot or mahogany styles and beads as may be correspondent with the sashes.

The same for 2½-inch sashes.

Fanlight frames over doors, which have nearly lost their employment from square lights having superseded them, are of —

1½-inch deal frames, square framed.

Ditto, semicircular head.

2-inch deal, square framed.

Ditto, semicircular head.

If elliptical, so describe them.

Sashes are to be described as follows: —

1½-inch deal ovolo (describe whether with circular head or circular on plan, if so).

2-inch deal ovolo (ditto).

2-inch deal astragal and hollow (ditto).

2½-inch deal astragal and hollow (ditto).

The above, if of wainscot, Honduras or Spanish mahogany, are to be so described, as also that they are to be hung single or double, as the case may be, with patent lines and iron weights, and patent sash-fastenings complete.

French casements are usually decribed as follows: —

2-inch deal ovolo casements. If with marginal lights or circular on plan, or both, describe them so; or if with astragal and hollow.

The same of 2½-inch, with the same modifications as in preceding article.

If either of the above be of wainscot, Honduras or Spanish mahogany, let them be so described.

It is usual to describe with these the hanging, which is commonly with 4-inch iron or brass butt hinges, and the species of fastening which it is common to place, at a sum varying from five to twenty shillings. When the turning Espaniolette fastenings are used, they must be particularly specified.

Shop-window sashes vary so much that we shall merely observe of their thicknesses, they are from 1½ to 2½ inches, and in the present extravagant rage for novelty among tradesmen, there is no end to the forms of their horizontal sections; — nothing, however *outré*, would be considered too extravagant for these people, and all that we can do is to say that, after describing their thickness, they are to be executed according to the drawings. In subjects of this kind, too, the *stall* *board*, and other fittings of the like nature, are to be specified in all, whereof the best way is to describe with reference to such drawings.

Friezes and cradling for cornices should always be referred to drawings, specifying generally their height.

Skylights, now usually made of metal; but if not, describe as follows: —

1½-inch deal ovolo skylight (if hipped, and with cross bars, state such).
2-inch deal ditto (ditto).
2½-inch ditto (ditto).

If astragal and hollow, or if of oak, such to be specified.

Kerbs for skylights are to be described —

1½-inch deal kerbs to circular skylights in two thicknesses, bevelled and chamfered.
2-inch ditto ditto.
2½-inch ditto ditto.

If elliptical, to be so specified.

Doors we shall, as in the preceding articles, describe, beginning with the commonest sort, for out-houses and the like.

¾-inch ledged wrought deal door.
Ditto, ploughed, tongued, and beaded.
1-inch wrought deal ledged ditto.
Ditto, ploughed, tongued, and beaded.
1¼-inch wrought deal ledged ditto.
Ditto, ploughed, tongued, and beaded.

1½-inch and 2-inch deal ledged doors are similarly described.

These doors may be hung with ⊢L or cross garnet hinges or with butt hinges, and with bolts, locks, latches, and other fastenings, as the case may require. External doors with 4-inch butts, if that be the sort used, and internal ones with 3½-inch butts.

Gates and coach-house doors are specified as —

2-inch deal, framed and braced, filled in with 2-inch deal, and ploughed, tongued, and beaded.
The same, filled in with battens.
2½-inch deal, framed and braced, filled in with 1-inch deal, ploughed, tongued, and beaded.
Ditto, filled in with battens.

If filled in with whole deal, it must be so specified.

2-inch deal bead butt and square gates, in eight panels.
2-inch deal bead butt and square gates, beadflush and square.
2-inch deal bead butt and square gates, bead flush on both sides.

If with more panels, or framed with a wicket, such must be specified.

The hanging of gates, and their hinges and fastenings, may be inserted according to the occasion of the work, at from 10*l.* to 15*l.* or even 20*l.*, which may be declared in the specification as to the value at which they are to be provided.

1-inch deal 1-panel square doors.
1-inch deal 1-panel square doors, folding.

The above are rarely used: we shall now, therefore, proceed by the number of panels, up to 6-panel doors, beyond which they are to be so particularly specified, or with reference to drawings.

1¼-inch, 2 panels, square.
1¼-inch, 2 panels, bead butt and square.
1¼-inch, 2 panels, bead flush and square.
1¼-inch, 2 panels, moulded and square.
1¼-inch, 2 panels, bead butt on both sides.
1¼-inch, 2 panels, bead butt and bead flush.
1¼-inch, 2 panels, bead butt and moulded.
1¼-inch, 2 panels, bead flush on both sides.
1¼-inch, 2 panels, bead flush and moulded.
1¼-inch, 2 panels, moulded on both sides.

When hung folding, to be so specified.

1½-inch deal, 2 panels, square.
1½-inch deal, 2 panels, bead butt and square.
1½-inch deal, 2 panels, bead flush and square.
1½-inch deal, 2 panels, moulded and square.
1½-inch deal, 2 panels, bead butt on both sides.
1½-inch deal, 2 panels, bead butt and bead flush.
1½-inch deal, 2 panels, bead butt and moulded.
1½-inch deal, 2 panels, bead flush on both sides.

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1½-inch deal, 2 panels, bead flush and moulded.
1½-inch deal, 2 panels, moulded on both sides.
2-inch deal, 2 panels, square.
2-inch deal, 2 panels, bead butt and square.
2-inch deal, 2 panels, bead flush and square.
2-inch deal, 2 panels, moulded and square.
2-inch deal, 2 panels, bead butt on both sides.
2-inch deal, 2 panels, bead butt and bead flush.
2-inch deal, 2 panels, bead butt and moulded.
2-inch deal, 2 panels, bead flush on both sides.
2-inch deal, 2 panels, bead flush and moulded.
2-inch deal, 2 panels, moulded on both sides.
2½-inch deal, 2 panels, square.
2½-inch deal, 2 panels, bead butt and square.
2½-inch deal, 2 panels, bead flush and square.
2½-inch deal, 2 panels, moulded and square.
2½-inch deal, 2 panels, bead butt on both sides.
2½-inch deal, 2 panels, bead butt and bead flush
2½-inch deal, 2 panels, bead butt and moulded.
2½-inch deal, 2 panels, bead flush on both sides.
2½-inch deal, 2 panels, bead flush and moulded.
2½-inch deal, 2 panels, moulded on both sides.

All these, as well as the following, must be specified as to be hung folding, if the nature of the work so requires.

1½-inch deal, 4 panels, square.
1½-inch deal, 4 panels, bead butt and square.
1½-inch deal, 4 panels, bead flush and square.
1½-inch deal, 4 panels, moulded and square.
1½-inch deal, 4 panels, bead butt on both sides.
1½-inch deal, 4 panels, bead butt and bead flush
1½-inch deal, 4 panels, bead butt and moulded.
1½-inch deal, 4 panels, bead flush on both sides.
1½-inch deal, 4 panels, bead flush and moulded.
1½-inch deal, 4 panels, moulded on both sides.
2-inch deal, 4 panels, square.
2-inch deal, 4 panels, bead butt and square.
2-inch deal, 4 panels, bead flush and square.
2-inch deal, 4 panels, moulded and square.
2-inch deal, 4 panels, bead butt on both sides.
2-inch deal, 4 panels, bead butt and bead flush.
2-inch deal, 4 panels, bead butt and moulded.
2-inch deal, 4 panels, bead flush on both sides.
2-inch deal, 4 panels, bead flush and moulded.
2-inch deal, 4 panels, moulded on both sides.
2½-inch deal, 4 panels, square.
2½-inch deal, 4 panels, bead butt and square.
2½-inch deal, 4 panels, bead flush and square.
2½-inch deal, 4 panels, moulded and square.
2½-inch deal, 4 panels, square, beat butt on both sides.
2½-inch deal, 4 panels, square, bead butt and bead flush.
2½-inch deal, 4 panels, square, bead butt and moulded.
2½-inch deal, 4 panels, square, bead flush on both sides.
2½-inch deal, 4 panels, square, bead flush and moulded.
2½-inch deal, 4 panels, square, moulded on both sides.
1½-inch deal, 6 panels, square.
1½-inch deal, 6 panels, bead butt and square.
1½-inch deal, 6 panels, bead flush and square.
1½-inch deal, 6 panels, moulded and square.
1½-inch deal, 6 panels, bead butt on both sides.
1½-inch deal, 6 panels, bead butt and bead flush.
1½-inch deal, 6 panels, bead butt and moulded.
1½-inch deal, 6 panels, bead flush on both sides.
1½-inch deal, 6 panels, bead flush and moulded.
1½-inch deal, 6 panels, moulded on both sides.

If the panels of 1½-inch doors are raised, or if double marginal doors, so describe them.

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Wainscot doors are usually as follow: —

1½-inch wainscot, 2 panels, square.
1½-inch wainscot, 2 panels, bead flush and square.
1½-inch wainscot, 2 panels, moulded and square.
1½-inch wainscot, 2 panels, bead flush on both sides.
1½-inch wainscot, 2 panels, bead flush and moulded.
2-inch wainscot, 2 panels, square.
2-inch-wainscot, 2 panels, bead flush and square.
2-inch wainscot, 2 panels, moulded and square.
2-inch wainscot, 2 panels, bead flush on both sides.
2-inch wainscot, 2 panels, bead flush and moulded.
2½-inch wainscot, 2 panels, square.
2½-inch wainscot, 2 panels, bead flush and square.
2½-inch wainscot, 2 panels, moulded and square.
2½-inch wainscot, 2 panels, bead flush on both sides.
2½-inch wainscot, 2 panels, bead flush and moulded.
1½-inch wainscot, 4 panels, square.
1½-inch wainscot, 4 panels, bead flush and square.
1½-inch wainscot, 4 panels, moulded and square.
1½-inch wainscot, 4 panels, bead flush both on sides.
1½-inch wainscot, 4 panels, bead flush and moulded.
1½-inch wainscot, 4 panels, moulded on both sides.
2-inch wainscot, 4 panels, square.
2-inch wainscot, 4 panels, bead flush and square.
2-inch wainscot, 4 panels, moulded and square.
2-inch wainscot, 4 panels, bead flush on both sides.
2-inch wainscot, 4 panels, bead flush and moulded.
2-inch wainscot, 4 panels, moulded both on sides.
2½-inch wainscot, 4 panels, square.
2½-inch wainscot, 4 panels, bead flush and square.
2½-inch wainscot, 4 panels, moulded and square.
2½-inch wainscot, 4 panels, bead flush on both sides.
2½-inch wainscot, 4 panels, bead flush and moulded.
2½-inch wainscot, 4 panels, moulded on both sides.
2-inch wainscot, 6 panels, square.
2-inch wainscot, 6 panels, bead flush and square.
2-inch wainscot, 6 panels, moulded and square.
2-inch wainscot, 6 panels, bead flush on both sides.
2-inch wainscot, 6 panels, bead flush and moulded
2-inch wainscot, 6 panels, moulded on both sides.
2½-inch wainscot, 6 panels, square.
2½-inch wainscot, 6 panels, bead flush and square.
2½-inch wainscot, 6 panels, moulded and square.
2½-inch wainscot, 6 panels, bead flush on both sides.
2½-inch wainscot, 6 panels, bead flush and moulded.
2½-inch wainscot, 6 panels, moulded on both sides.
2-inch wainscot *sash-doors*, with diminished stiles, lower panel moulded, bead flush, with astragal and hollow sash.
2-inch wainscot sash-doors, with diminished stiles, lower panel moulded, bead flush, with astragal and hollow sash, moulded on both sides.
2½-inch wainscot sash-doors, diminished stiles, lower panels moulded, and bead flush, with astragal and hollow sash.
2½-inch wainscot sash-doors, diminished stiles, lower panels moulded, and bead flush, with astragal and hollow sash, moulded on both sides.

If any of these are to be hung folding, double margined, or moulded on the raising, such must be specified.

Mahogany doors as follows: —

2-inch Honduras mahogany doors, 2 panels, moulded and square.
2-inch Honduras mahogany doors, 2 panels, moulded on both sides.
2-inch Honduras mahogany doors, 4 panels, moulded and square.
2-inch Honduras mahogany doors, 4 panels, moulded on both sides.
2-inch Honduras mahogany doors, 6 panels, moulded and square.
2-inch Honduras mahogany doors, 6 panels, moulded on both sides.
2½-inch Honduras mahogany doors, 4 panels, moulded and square.
2½-inch Honduras mahogany doors, 4 panels, moulded on both sides.
2½-inch Honduras mahogany doors, 6 panels, moulded and square.

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2¼-inch Honduras mahogany doors, 6 panels, moulded on both sides.

If any of these are hung folding, with projecting mouldings, or with double margins, it must be so specified. The last set of doors, if required to be of a better description, may be specified of the best Spanish mahogany.

2-inch Honduras mahogany sash-door, astragal and hollow bottom, panel moulded and square.

2-inch Honduras mahogany sash-door, astragal and hollow bottom, panel moulded on both sides.

2¼-inch Honduras mahogany sash-door, astragal and hollow bottom, panel moulded and square.

2¼-inch Honduras mahogany sash-door, astragal and hollow bottom, panel moulded on both sides.

If hung folding, or with double margin, or diminished stiles, to be so specified.

External doors are of varieties, as follow: —

2-inch deal, 4 panels, the lower panels bead butt and square, and the upper panels square both sides.

2-inch deal, 4 panels, the lower panels bead butt and square, and the upper panels bead butt on the back.

2-inch deal, 4 panels, the lower panels bead butt and square, and the upper panels bead flush on the back.

If the panels have raised mouldings, specify them.

2¼-inch deal, 4 panels, the lower panels bead butt and square, upper panels square on both sides.

2¼-inch deal, 4 panels square, bead butt on the back.

2¼-inch deal, 4 panels square, bead flush on the back.

Specify raised mouldings, if any.

2-inch deal, 6 panels, lower panels bead butt and square, upper panels square both sides.

2-inch deal, 6 panels, lower panels bead butt and square, upper panels square, bead butt on the back.

Specify raised mouldings, if any.

2¼-inch deal, 6 panels, the lower panels bead butt and square, and the upper panels square both sides.

2¼-inch deal, 6 panels, the lower panels bead butt and square, and the upper panels square, bead butt on the back.

2¼-inch deal, 6 panels, the lower panels bead butt and square, and the upper panels square, bead flush on the back.

If with raised mouldings, so describe them; also, if double margined, &c.

Any of these external doors, if hung folding, or with circular or curved heads, must be so specified.

Sash doors are of the following varieties: —

1½-inch deal, 2 panels, square, diminished stiles, and ovolo sash.

1½-inch deal, 2 panels, bead butt and square, diminished stiles, and ovolo sash.

1½-inch deal, 2 panels, bead flush and square, diminished stiles, and ovolo sash.

1½-inch deal, 2 panels, moulded and square, diminished stiles, and ovolo sash.

1½-inch deal, 2 panels, moulded and bead butt, diminished stiles, and ovolo sash.

1½-inch deal, 2 panels, moulded and bead flush, diminished stiles, and ovolo sash.

1½-inch deal, 2 panels, moulded on both sides, diminished stiles, and ovolo sash.

2-inch deal, 2 panels square, diminished stiles, and ovolo sash.

2-inch deal, 2 panels, bead butt and square, diminished stiles, and ovolo sash.

2-inch deal, 2 panels, bead flush and square, diminished stiles, and ovolo sash.

2-inch deal, 2 panels, moulded and square, diminished stiles, and ovolo sash.

2-inch deal, 2 panels, moulded and bead butt, diminished stiles, and ovolo sash.

2-inch deal, 2 panels, moulded and bead flush, diminished stiles, and ovolo sash.

2-inch deal, 2 panels, moulded on both sides, diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, square, with diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, bead butt and square, diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, bead flush and square, diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, moulded and square, diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, moulded and bead butt, diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, moulded and bead flush, diminished stiles, and ovolo sash.

2¼-inch deal, 2 panels, moulded on both sides, diminished stiles, and ovolo sash.

If hung folding, or with marginal lights, to be so described.

It is the practice in describing joiner's work, to specify the ironmongery used with it, that is, the hinges, locks, fastenings, and furniture; and we have accordingly mentioned the hanging and fastening of common doors, and gates, and coach-house doors

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Common framed 4-panel doors are usually hung with 3½-inch butts and 7-inch iron rim stock locks. Better doors are hung with 4-inch iron or brass butts, mortice locks and brass nob furniture. Folding doors, if heavy, should have 4½ or 5-inch brass butts, and if necessary to clear mouldings, they should be hung with projecting brass butts, and should moreover be provided with flush and other bolts, and mortice locks and furniture. Doors of dining, drawing, and other rooms, where they are required to clear the carpet by rising as they open, should have 4 or 4½-inch rising joint butts. For closet doors, 3½-inch butts are usually described with brass tumbler locks and keys. External doors require the provision of larger locks, which are usually iron rim locks with 10 or 12-inch bright rod bolts, chains, staples, &c. Shutters when hung are with butts, which for the back flaps are of a less size, and spring bar fastenings should be specified to them. Brass nobs to the front flaps.

Moulded architraves to doors and windows are described by their width.

Columns and pilasters are usually described —

1¼-inch deal diminished columns, . . . inches diameter.

1½-inch deal diminished columns, . . . inches diameter.

Pilasters similarly specified. Both one and the other to be glued up and blocked.

If fluted, to be mentioned; as also necking grooves to columns. Caps and bases according to the order, carved or of papier maché, as the expense will allow.

Entablatures got out of deal, as per drawing, provide glued, blocked, and fixed with all necessary brackets and grounds.

Water-closets are fitted up with 1-inch clean deal (wainscot or mahogany), seats, risers, and clamped flaps, square skirtings, all requisite bearers and pipe-casing; and the joiner is to attend on the plumber while fixing the basins and other work. *Privies* are described as to seats and risers the same as water-closets.

Cisterns, internal and external, must have their cistern cases proportioned in thickness to their sizes; thus one about 3 or 3 feet 6 inches long, and 2 feet 9 inches deep, will do on 1¼-inch deal dovetailed· it should be described with requisite bearers, and a cover of ¾-inch deal with a wood handle. For a good-sized external cistern, we should specify, provide and fix a wrought and dovetailed 2-inch deal cistern case, . . . feet long, . . . feet wide, and . . . feet deep in the clear. Find and fix all necessary bearers for the same, together with all other requisite fittings, and further provide a ¾-inch deal strongly ledged cover, with saddle-back fillets and water channels at each joint, as shall be directed.

Cisterns for water-closets.

Each to have cistern cases of 2-inch deal capable of containing 36 cubic feet of water, fixed with strong bearers and ledged covers of ¾-inch yellow deal tongued and beaded.

Sinks, describe as under, when wooden ones lined with lead are used.

1½-inch dovetailed sink, enclosed with 1¼-inch deal square-framed front, and door hung with 3-inch butts and other necessary ironmongery.

Warm bath.

To be fitted up (of the best Spanish mahogany) with riser, frame, and clamped flap, provided and fixed with all requisite bearers and other fittings and appurtenances. The flap to be moulded in front, and hung with 3½-inch butt hinges, and the riser panelled and moulded as shown in the drawings.

Dressers. The following is a specification for a good house.

Provide and fix a dresser in the kitchen, of 2-inch deal, with cross-tongued top 10 feet long and 2 feet 9 inches wide, supported on strong framed legs and bearers. 1-inch deal pot-board and bearers. Six 1½-inch sunk shelves, whose widths are to average 7 inches. Back of the shelves to be of 1-inch deal, wrought, beaded, grooved, and cross-tongued. 1-inch deal top, 14 inches wide, with moulded cornice. Five drawers with bottoms and dovetailed rims of ¾-inch deal. The fronts to be of 1-inch deal, beaded. A brass drop handle and a good patent tumbler lock to each drawer, together with all slides, runners, bearers, and other requisite appurtenances.

Dresser top for scullery, 1½-inch clean deal, 2 feet 6 inches wide and 6 feet long, cross-tongued and fixed upon strong wrought and framed legs and bearers.

Plate-rack for scullery to be provided over the sink, and of the same length. Sink as above described.

Spit-rack to be provided over the kitchen chimney, or other convenient place, as may be directed.

Dwarf closets, if any are used, may be of 1-inch deal, square framed and moulded in front, the doors to be hung with 2½-inch butts, and to have tumbler locks.

Pipe casings, wrought and framed, to be provided where necessary, to hide lead pipes of all descriptions, and fronts to unscrew for coming at the pipes in case of defects therein.

Carpenter and Joiner.

Fittings for larder, as follow: —

Provide a clean deal dresser top, 1½ inch thick, 2 feet 6 inches wide, and . . . feet long, to be feather-tongued and fixed on strong framed legs and rails. Two meat rails, 6 feet long, of wrought fir, 3½ by 2 inches, suspended from wrought iron stirrups. Provide also a hanging shelf, 6 feet long, 10 inches wide, and 1¼ inch thick, to be similarly suspended by wrought iron stirrups.

Laundry to be fitted up with 1½-inch clean white deal washing troughs, wrought two sides, and splayed and put together with white lead, as shown on drawing. 1¼-inch deal ironing board, wrought both sides and clamped, properly hung with hinges to a hanging stile. Provide two clothes racks, hung with pullies and ropes to the ceiling to raise and lower the same.

Dust bin, with proper slides, where shown on the plan, to contain 30 feet cube, the whole to be of oak.

Arris gutters to eaves should never be of wood: zinc or copper are better materials, and we do not therefore think it necessary to describe them.

Fittings to shops are so various that no general description can be given. They must be referred to drawings, and on them the specification should be written. So of *shop fronts*.

Stable fittings are specified as follow: —

Mangers, &c. 2-inch deal bottoms and 1½-inch deal sides. Wrought oak manger-rails, 4 by 3 inches. Wrought, rebated, and rounded oak manger post, 6 by 4 inches, wrought and framed with bearers thereto. Oak heel-posts, wrought, 6 by 5 inches, and groove for partitions. Oak top rails, 5 by 4 inches, grooved and rounded at the top. Oak bottom rails, wrought, 4 by 4 inches, grooved and arris rounded off. 1¼-inch deal partitions, wrought on both sides, ploughed, tongued, and beaded. 1¼-inch deal rails on each side, board wide, and the arrisses rounded off.

Fronts to hay-racks. Oak standard, 4 by 4 inches, wrought and framed into oak bearer under the manger. 1¼ inch deal fronts framed for the reception of cast-iron hay-racks well secured. Fix fir bearers and 1-inch deal partitions at each end of hay-racks, with fir arris rails 3 inches apart at the bottom of each rack.

Dressings over stalls connected with heel-posts. 1-inch deal frieze, wrought joints, feather-tongued, and backings thereto, segmental sofites and keystone in centre of arches. Impost moulding at the springings and moulded cornice to girt about 10 inches.

Line the walls to the height of 5 feet with 1-inch yellow deal, wrought, ploughed, tongued, and beaded, with a ⅝-inch beaded capping thereon.

Churches. To give general directions for the specification of a church would be impossible. The principles of its timbering may be collected from what has preceded. *Pewing* is executed as planned on the drawings, of whole deal (generally) square-framed partitions two panels high; 1½-inch framed doors and enclosures one or two panels high, with stiles, munnions, and top rails 3 inches wide, and bottom rails 6 inches wide. The panels of the doors and enclosures should not be more than a board in width, and the framework round them chamfered. The doors are hung with 3-inch butt hinges, and should have brass nob pulpit latches. Capping to the whole of the pewing, grooved and moulded according to drawing. *Pew fittings* are, 1½-inch wrought and rounded seats 12 inches wide, with proper bearers and 1¼-inch cut brackets not more than 3 feet apart. Seats rounded next the pew doors. *Flap-seats* in the galleries to have strong joints. All the pews to have ¾-inch book boards 6 inches wide, with ½-inch rounded capping bearers, and ½-inch cut brackets thereunder, not more than 2 feet 6 inches apart, and the ends rounded next the pew doors. If there be an organ, its enclosure and the free seats adjoining it should correspond with the pew enclosures. *Free seats* of 1¼-inch deal, as shown in the drawings. The seats to be 11 inches wide, rounded in front. Backs framed with stiles, munnions, and rails, 3½ inches wide, and the standards, ends, and bearers, according to the drawings. *Children's seats* to be of 1¼-inch deal, with brackets same thickness, not more than 2 feet 6 inches apart; at least 8 inches wide, and the flap seats, where they occur, to be hung with strong butts. *Pulpits and reading desks* are usually of 1¼-inch deal, framed according to drawings, with 1¼-inch doors, hung with brass hinges and pulpit latches. Whole deal floors on bearers, 1-inch book boards, cappings and bearers. 1-inch clean deal or wainscot steps and risers, moulded returned nosings, 1¼ inch, beaded, sunk and cut string boards, strong bracketed carriages. 1-inch square framed sofite under pulpit floor and stairs, mahogany or wainscot moulded handrail, with caps turned and mitred; square bar balusters with one in ten of iron; turned newels to block steps; seats of 1¼-inch deal, 13 inches wide, and proper bearers thereto, together with all appurtenances and requisite fittings for executing the drawings.

Carpenter and Joiner.

The carpenter and joiner is to provide all such jobbing work, in following or preceding the other artificers engaged on the works and their appurtenances, as may be requisite for the completion thereof in every respect, without any extra charge.

2286. Founder, Smith, and Ironmonger. For describing cast iron girders and columns, reference must be had to Chap. II. Sect. V. (1753, *et seq.*), wherein will be found the method of determining their scantlings — for which no rule can be given that is not dependent on the results there laid down. Having determined the weight to be borne, no girder (and such should be inserted in the specification) should be allowed to be used, that has not been previously tested by *weighing* it at the foundery.

Cast iron cradles are sometimes used for openings, which must be described for the particular occasions as they occur.

Chimney bars are described usually as follows: —

Provide and fix to kitchen chimney two wrought iron cradle bars, each 2 inches wide and ¾-inch thick, long enough to extend to the outside of the chimney jambs, and turned up and down at each end. The other chimneys are to have wrought iron chimney bars 3 inches wide and ½ inch thick.

Straps, stirrup irons, nuts, bolts, screws, and washers, together with all other wrought iron work for the roofs and partitions, to be provided, as may be requisite for tying in and securing all carpentry, and the smith is to deliver to and assist the carpenter in fixing or attaching the same.

Where the quantity is uncertain, a given weight beyond the above general direction should be provided in the contract, such part thereof as may not be wanted to be deducted from the accounts after the rate of . . . per cwt.

Provide all necessary cramps of cast and wrought iron, as may be directed, for the mason, the former to be used where the works are exposed to the air.

Wrought iron doors to be provided for strong room (or if opening in a party wall), folding, and of the best quality, as shown in drawing; with hinges and proper fastenings, of the value at least of 25*l.*

If *cast iron sashes* are used in any part of a building, they are to be provided with reference to drawings.

Wedges for underpinning must be described with reference to the thickness of walls they are to catch: each pair must be at least as long as the wall is thick.

Balusters to a back stone staircase and landings are described —

Wrought iron balusters, ¾ inch square, with turned wrought iron newel equal to 1½ inch diameter, with rounded handrail of wrought iron 1½ by ½ inch. The balusters and newel are to be riveted into the handrail at top, and at the bottom let into the stone work and run with lead.

Balusters to a principal staircase are described —

Ornamental cast iron balusters, as shown on the drawings, with top rail of wrought iron 1½ by ½ an inch, let into and firmly screwed to the mahogany (or wainscot) handrail. The balusters and newels are to be riveted into the iron rail, and at the bottom they are to be let into the stonework and run with lead

Balusters of wrought iron to be provided for strengthening the principal staircase when not of stone. Every tenth baluster to be of wrought iron, properly fastened.

Provide and fix . . . knockers for . . . doors to . . . .

Air bricks of cast iron to be provided and fixed in the brickwork for the ventilation of the floors.

Air gratings, . . . in number, to be provided, 9 inches square, and fixed round the lower part of the walls of the house.

Area gratings, . . . to each area (if any there be), to be prepared and fixed of cast iron, with bars 1½ inch by ¾ of an inch, and not more than 1½ inch apart. Frames 1½ inch by 1 inch, and with strong flanges to let into the surrounding stone-work.

Window guards of wrought iron to the windows of . . ., and . . . bars to be 1 inch square and 4 inches apart, with framework of iron of the same substance securely fixed to the brickwork.

Cast iron rain-water pipe, for a large size stack, is described —

6 inches diameter, to lead from the roof down into the drain, with head and shoe complete.

Coal plates (if more than one) of cast iron, with proper fastenings to be fixed over the coal shoot.

Cast iron ornamental railing, as per drawing, to the windows, or to the stone balcony in front of the house, as the case may be.

Air traps of cast iron to all communications of surface water with drains to be of appropriate size, and provide all gully-hole gratings that may be necessary.

To provide for the carpenter's and joiner's works, and use and fix thereto, besides that

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which has been already described, all requisite spikes, nails, screws, and other proper ironmongery, and all requisite brass work, both to be of the very best quality.

Provide a copper, . . . inches diameter, and stewing stoves as shown on the drawings, with all requisite bars and iron work.

For fittings to stables describe —

No. . . . Cast-iron hay-racks, 3 feet wide and 2 feet high in the clear. 1¼-inch round staves, about 3 inches apart, the frames 1¼ by ¾ of an inch, with the arris rounded off next the staves. Provide and fix two manger rings in each stall.

Cast iron coping to the walls of the dung-pit of the thickness of ⅞ of an inch, and returned on each side 4 inches down at the least.

Cast iron gratings to stable yards are usually described as of the weight of 1 cwt.

For church and chapel work, the founder's, smith's, and ironmonger's work is so dependent on the design, that no general instructions for specifications can be given. The following are the only peculiarities: —

Provide *cast iron saddle bars* for the windows ⅝ by 1¼ inch, 12 inches longer than the clear width of each window, laid into and worked up with the brickwork, at the height shown on the drawings.

Provide to each window wrought iron framework for a hopper casement, as shown on the drawings, and fit up the same complete, with patent lines, brass pulleys, and all other requisite appurtenances.

2287. Plasterer. To *lath, plaster, float,* and *set* all the ceilings and strings of staircases, and the quartered partitions of the . . . chambers (such as servants' rooms) on attic stories.

To *render, float,* and *set* all brickwork in attic stories.

To plaster all sides of the kitchen offices and office passages with best floated rough stucco, lathed where requisite.

All the remainder of the sides of the interior throughout is to be executed with the very best floated stucco, lathed where requisite. Stucco of offices (or office buildings if any) to be finished with rough surfaces; all the rest of the stucco to be troweled quite smooth.

All the arched, groined, panelled, and coffered work, and the bands and architraves, to be executed in guaged stuff, in the best and most accurate manner.

To run plaster cornices round the several rooms, lobbies, passages, and other parts of the building, with enrichments thereto accurately modelled according to the drawings (the enrichments, if so wished, to be described as of papier maché). A centre flower to each room on the ground and one-pair floor, where marked, securely fixed to the ceiling. These are, on all accounts, better for security in the papier maché, as they can be then screwed to the ceiling.

Basement or ground story (or both, as the case may be) is to be run round in all the rooms, lobbies, passages, &c. with *skirtings of Parker's cement*, 10 inches high, 1¼ inch thick, whited when soft, and finally washed of stone colour.

The plasterer is to execute all necessary beads, quirks, and arrisses. To stucco all internal and external reveals, to dub out where the work may require it, so as to bring out all extra thicknesses and projections, and to counter-lath the work over large timbers and elsewhere, as may be necessary.

The lathing throughout is to be performed with lath-and-half heart of fir laths, free from sap. Enrichments to be carefully trimmed and finished off, and where heavy leaves or embossed work may require it, to be screwed with strong copper screws.

The ceilings on the two principal floors are to be distempered by the painter. All the rest of the ceilings, strings, and mouldings are to be whitened.

The sides of the rooms in the attic or garrett (as the case may be) stories, as well as the lobbies, closets, passages, &c., are to be finished of such stone colour tints as the architect may direct.

Lime-white stables and coach-house walls, larders, sculleries, cellars, including vaulting under sides of floors where open, &c.

When Parker's cement is used for external works, describe as under: —

To stucco in the very best manner with Parker's cement, jointed to imitate masonry, the whole (or part, if such be the case) of the exterior of the building, with columns, pilasters, plinths, entablatures, strings, mouldings, labels, jambs, reveals, chimneys, chimney moulds, decorations, enrichments, and appurtenances of every kind, as shown on the drawings and profiles. Such works to be subject to such further instructions from the architect as he may think proper, and to be roughly coloured as each portion is executed, and finally coloured when the architect shall so direct, with weather-proof colour-

PLASTERER.

ing, fixed with Russia tallow, beer grounds, tar, and the other proper ingredients.

Where desired, decorative chimney moulds, of Parker's cement, and of the value of two guineas, to be provided for each flue.

Pugging. To fill in upon the sounding boarding between the joists, where so provided, with good lime and hair pugging mortar, laid throughout 1 inch in thickness.

Roughcasting. For the mode of describing this, see Plastering, Sect. IX. (2249.)

2288. **PLUMBER.** To lay the *flats and gutters* with milled lead of 8 lbs. to the foot superficial. Where against walls, to be turned up 7 inches; where against slopes, as rafters, to turn up 10 inches. Rolls not to exceed 27 inches apart.

Work *flashings* of milled lead in the walls of 5 lbs. to the foot, and to turn down over gutters and flats. Where flashings adjoin the slopes of a roof, they should be described to be laid stepwise into the brickwork, and of an average width of 12 inches.

Hips and ridges to be covered with milled lead 6 lbs. to the foot, and at least 18 inches wide, well secured with lead-headed nails.

Where eaves gutters are used, describe as follows: —

To put round the eaves at the curb plate 4-inch copper (or zinc) guttering, fixed complete with bands and brackets, with copper (or zinc) pipes . . . . inches diameter, with neat heads and appropriate shoes to lead into the gutter or drain.

Domes should be covered with lead from 6 to 8 lbs. to the foot superficial, according to their size, and must be well secured with proper seams or rolls thereto.

For coverings of zinc the reader is referred to Sect. VII. Chap. II. (1792, *et seq.*) of this Book, where the thicknesses will be found.

Tops and sides of dormers to be covered with 5-lb. milled lead, turned down all round full 8 inches. A flashing of 5-lb. milled lead 30 inches wide, to be fixed over the sill of the dormer door or window, as the case may be.

Aprons of 6-lb. milled lead, and 10 inches wide, should be described to sky-lights.

External mouldings of wood should be covered with 6-lb. milled lead, to turn up 6 inches, and to have flashings of 4-lb. milled lead let into the brickwork, and to be turned down 5 inches.

To fix . . . . *stacks of rain-water pipes* from the gutters to the drains, of (5) inches bore, turned up from milled lead of 8 lbs. to the foot superficial, and securely fixed with ornamental cistern heads as shall be approved by the architect, and 2-inch strong overflow discharging pipes. Similar description for conveying water from a portico.

No pipes but of lead or zinc should be used against stone buildings. Cast iron pipes should only be used to offices.

In London, it is usual to specify that the water should be laid on for the service of the house in the following manner: —

To lay on from the main of the . . . . Company water with ¾-inch strong cast lead pipe to the cistern of the upper water-closet, with ball-cock complete. Similarly to lower water-closet and to such other cisterns as are provided, with ball-cocks, &c. complete, and to pay all official fees.

Line the sinks in the scullery and butler's pantry (and other small ones, if any) with 6-lb. milled lead, and fix thereto 2-inch waste pipes, with brass bell traps complete to go into the drains.

Line the kitchen cistern with milled sheet lead, bottom 9 lbs. and sides 6 lbs. to the foot, with all soldering thereto. To provide to the same a 1¼-inch waste pipe. Line the kitchen sink with lead of 8 lbs. to the foot, to turn well over the woodwork and to have a 2-inch strong waste pipe to lead into the drain, with brass bell grate complete. A ¾-inch service pipe and brass cock to be provided from the cistern for supplying water to the sink.

Roses pierced with holes of sufficient dimensions to be provided of 10-lb. lead to gutters and rain-water cesspools.

Water closets to be constructed and fitted up in every respect complete, with blue basin, the very best patent valve apparatus. Soil pipe of 8-lb. lead and 4½-inch bore to lead into drain with strong D trap, lead box 10 inches by 7 and 6 inches deep, of milled lead 10 lbs. to the foot. 1-inch supply pipe to the basin, and all other pipes, wires, cranks, handles, and other proper fitments. The cistern is to be lined, bottom with 8-lb. cast lead, and sides with 5-lb. milled lead. 1¼-inch waste pipe, soldered in below the dip, with washer and waste complete.

Inferior water closets to be provided with strong cast iron trapped basin, with water laid on, and in all respects to be fitted complete.

Provide all stink-traps that may be requisite where the pipes communicate with the drains.

Plumber.

For cold bath, lay on the water with strong 1¼-inch lead pipe, with brass cock, and fix 2¼-inch strong lead waste pipe, with brass washer and plug thereto.

If the hot bath be not of marble, describe as follows: —

Provide and fix a hot bath of copper of 16 ounces to the foot superficial, tinned on the inside, and painted in japan to imitate marble as may be directed. Lay on the water thereto, with waste pipe, cock, water plug, and all other proper fittings as for cold bath.

Common pumps are generally described as 3-inch pumps, with neat cast iron cases fixed complete, with proper lead suction pipe to bring sufficient supply of water from well, and all other appurtenances.

To provide and fix (this where the water is not laid on, as in London) a 3½-inch lifting engine pump, with brass barrel; and provide from the well . . . feet of 1¼-inch strong suction pipe. Service pipes as may be necessary to the cisterns, with all cocks and joints that may be necessary.

Provide all copper nails that may be wanted for laying the works.

To provide in the contract . . . . cwt. extra of cast sheet lead, including labour and all proper materials as may be wanted and directed by the architect; and if the same or any part thereof should not be used, there shall be a deduction made for the same on making up the accounts, after the rate of . . . . per cwt. for such portion thereof as shall not have been used.

2289. **Glazier.** To glaze all the windows with the best Newcastle crown glass, or for offices with second Newcastle crown glass.

The whole of the glazing is to be properly bedded, sprigged, and back-puttied, and to be left whole and clean on the works being rendered up as complete.

When plate glass is to be used, the same must be specified, and the architect must direct the manufactory from which it is to be procured.

2290. **Painter.** To knot with silver leaf, pumice down and smooth, and otherwise prepare all the wood and other works intended for painting.

To paint four times in oil, with the best oil and colour, all the internal and external wood and iron works, all the stucco, and all other works that are usually painted.

The walls of the principal staircase, lobbies, and entrance hall are to be imitations of marbles, jointed like masonry, as shall be directed, and varnished twice over with best copal.

The doors, shutters, dadoes, skirtings, boxings, architraves, and other dressings on the ground and one-pair floors (and others if required), are to be grained wainscot (or other wood as may be specified), in an artist-like manner, and varnished twice with best copal varnish.

If mouldings of doors and shutters are to be gilt, specify the same.

The ceilings and cornices on ground and one-pair floor to be painted four times in oil, and flatted and picked in such extra colours as may be directed.

To flat extra, of such tints as may be directed, all the rest of the stucco work and wood work on the principal and one-pair floors.

Sashes to be finished on the outside of . . . . colour. The plain painting to be of tints of brown, drab, or stone colour as may be directed.

Distemper ceilings (this to be specified if any are so intended), or paint if intended.

2291. **Paperhanger.** To prepare and bring to a proper face all the walls and surfaces intended for papering.

To underline with proper paper, and hang with paper of . . . . pence per yard, the rooms on the one-pair floor, and to provide and fix gold beads thereto . . . . inches wide: borders, if thought proper, to be specified.

To hang with figured paper, value . . . . per yard, the rooms (to be described) on the . . . . floor, with borders.

The remainder of the rooms are to be hung with paper . . . . per yard, with borders.

All the patterns are to be approved of by the architect.

2292. **Bellhanger.** To provide and fix with all necessary wires, pulls, cranks, and every other appendage, bells from the following places: — [Here enumerate the places.]

2293. We now close the general view of a specification (which has been submitted as nothing more than a skeleton for filling up as different cases may require; to make one which would serve all purposes is obviously impossible) by adding the usual form of a contract.

2294. CONDITIONS. That all the works shall be executed in the best and most workmanlike manner, to the satisfaction of [Here add employer's name], or his architect, without reference thereon to any other person. If any alterations should hereafter be made by order of (*the employer*), or his architect, by varying from the plans or the foregoing specification, either in adding thereto or diminishing therefrom, or otherwise however, such alterations shall not vacate the contract hereby entered into, but the value thereof shall be ascertained by the said architect, and added to or deducted from the sum hereinafter mentioned, as the case may be; nor shall such alterations, either in addition, diminution, or otherwise, supersede the condition for the completion of the whole of the works, but the contractor shall, if such alterations, of whatever sort, require it, increase the number of his workmen, so that the same, as well as the works contained in the above particulars, shall be completely finished, and so delivered up to (*the employer*), on or before the day of , in the year , on failure whereof the contractor shall forfeit and pay to (*the employer*), the sum of for every day that the work remains unfinished and undelivered as aforesaid, which sum the said (*the employer*) shall be allowed to stop as liquidated damages out of any moneys that may be due and owing to the said contractor on account of the works.

If any doubt or doubts should arise during the execution of the works, or at measuring the extras should any occur, or at making out the accounts as to any extras or other works for which the contractor may consider he may have a claim, over and above the sum hereinafter mentioned, the admission and allowance of any such claim or claims shall be judged of, determined, and adjusted solely by the architect to (*the employer*), without reference in any way to any other person; it being the intention of these conditions that all such works of every kind that may be necessay for completely finishing the works proposed, for the rectification of any failure from whatever cause arising, and the well maintaining, sustaining, and supporting the whole of the works, as well as alterations and additions, should such be made, so that the whole may remain sound and firm, are implied in the foregoing specification, although the same may not therein be specifically expressed, and that on this, as well as all other matters, no reference to any other person than the aforesaid architect is to be allowed or admitted.

If the contractor should neglect or refuse to carry on the works with such dispatch as is thought proper by the architect, it shall be lawful for (*the employer*) or his architect, and either of them is hereby empowered to employ such other person or persons as (*the employer*) or his architect, or either of them, may think fit or necessary, to finish and complete the several unfinished works, after having given notice thereof in writing six days before employing such person or persons, such notice to be left either at the contractor's shop, counting-house, or usual place of abode, without effect, and the amount or amounts of the bill or bills of any artificers that may be so employed shall be deducted out of any moneys that may be due and owing to the said contractor, or any part thereof, as the case may be.

It is hereby agreed, this day of , in the year , between (*the employer*), on the one part, and (*the contractor*) on the other part, that he, the said (*the contractor*), for his executors, administrators, and assigns, doth hereby promise and agree to and with the said (*the employer*), to do and perform all the works of every kind mentioned and contained in the foregoing particulars, and according and subject to the conditions above recited, and according to the plans prepared and referred to, at and for the sum of pounds; and the said (*the contractor*) doth hereby agree to abide by and be subject to the several clauses, conditions, and penalties hereinbefore mentioned and contained.

In consideration whereof the said (*the employer*) doth hereby promise and agree to pay to the said (*the contractor*), on the certificate of the architect, the aforesaid sum of pounds, in separate payments, it being agreed that neither of the said payments, except the last, shall amount to more than two thirds of the value of the work done at the time of such certificate being given.

In witness whereof the said parties have hereunto set their hand, the day and year above written.

A. B. (the employer.)
Witness, E. F. C. D. (the contractor.)

Sect. XIV.

MEASURING AND ESTIMATING.

2295. The practice of measuring is dependent on rules already given under Mensuration, in Sect. VII. Chap. I. of this Book (1212, *et seq.*), in which are described the methods of ascertaining the superficial and solid contents of any figure. The application of them to architecture, in the practice of measuring and estimating the different parts of a building, forms the subject of this section.

2296. For the purposes of measuring, the common instruments are a pair of 5-feet rods, divided into feet, inches, and half inches, and a 2-feet rule divided into inches and eighths and twelfths of inches, beyond which subdivision measurements are rarely carried in this country.

2297. The mode of what is called squaring dimensions, as usually practised, is given under Section I. Arithmetic &c., in this Book (868, *et seq.*), to which the reader must refer, if not already fully informed on that head. We shall now at once proceed to the general principles on which the measurement and estimation of work in the several artificers' departments are conducted.

2298. Digging is performed by the solid yard of twenty-seven cubic feet (that is, 3 feet × 3 feet × 3 feet = 27 feet). Where the ground is soft in consistence, and nothing more is necessary beyond cutting with a spade, a man may throw up a cubic yard per hour, or 10 cubic yards in a day; but if of firmer quality, *hacking* becomes necessary, and an additional man will be required to perform the same work; if very strong gravel, more assistance will be required. If, therefore, the wages of a labourer were 2*s.* 6*d.* per day, the price of a yard would be 3*d.* for cutting only, without profit to the contractor; 6*d.* for cutting and hacking, and 9*d.* if two hackers be necessary. In sandy ground, where wheeling becomes necessary, three men will remove 30 cubic yards in a day to the distance of 20 yards, two for filling and one for wheeling. But to remove the same quantity in a day to a greater distance, an additional man for every 20 yards will be required.

2299. The method of ascertaining the quantity of excavation will, of course, be obvious; the quantity is the length multiplied into the depth and width. In the cases of trenches merely dug for the reception of walls, which, of course, are sloped to prevent the earth falling in on the excavators, a mean width is to be taken. Thus, suppose an excavation 24 feet long, 4 feet wide at top, and 2 feet at the bottom (average width therefore 3 feet), and 5 feet deep, we have for the quantity of yard $\frac{24 \times 3 \times 5}{27} = 13{\cdot}07$ cube yards.

2300. Brickwork. In measuring and estimating the value of brickwork, the following points must be remembered. A rod of brickwork is a mass 16½ feet square; hence the quantity of superficial feet which it contains is 272¼ feet (16·5 × 16·5), but the ¼ of the foot is too trifling to make it worth while to embarrass calculations with it, and consequently 272 feet is universally taken as the superficial standard content of a rod. Its standard thickness is one brick and a half (or 13½ inches). Hence it follows, that a cubic rod of brickwork would be 272 feet × 13½ inches = 306 feet cube. The allowance for the number of bricks is taken on an average at 4500. Much, however, depends on the closeness of the joints and the nature of the work. In walling, a reduced foot is generally taken as requiring 17 bricks; a foot superficial in Flemish bond, laid in malm facing, about 8 bricks; and a foot superficial of guaged arches, 10 bricks. In paving, a yard requires 82 paving bricks, or 48 stock bricks, or 144 Dutch clinkers laid on edge, or 36 bricks laid flat.

2301. In tiling, which is measured by the square of 100 superficial feet, a square will require 800 at a 6-inch guage, 700 at a 7-inch guage, and 600 at an 8-inch guage. The guage necessarily regulates the distance of the laths, and, at the same time, must be dependent on the slope of the roof, which, if flat, should not be less than 6 inches, as for instance, above the kerb in a kerb roof; and not more than 8 inches in any case. A square of plaintiling requires about on an average a bundle of laths, two bushels of lime, and one of sand, and at least a peck of tile pins. The laths are sold in bundles of 3, 4, and 5-feet lengths. A bundle of the 3-feet contains eight score, the 4-feet six score, and the 5-feet five score to the bundle. The nails used are fourpenny; they are purchased by the long hundred, that is, of six score, and, in day work, are charged by the bricklayer 5-score to the hundred. The name of nails, as fourpenny, fivepenny, &c., means fourpence, fivepence, &c. per hundred. The numbers of nails required for a bundle of 5-feet and 6-feet laths, are 500 and 600 respectively.

2302. A square of pantiling requires 180 tiles laid at a 10-inch guage, and a bundle of 12 laths 10 feet long.

2303. In lime measure, what is called a hundred is 100 pecks, or 25 striked bushels (old measure).

2304. In sand measure, 18 heaped bushels, or 21 striked bushels, equal to 1 yard cube, is a single load, and about 24 cubic feet 1 ton.

2305. In mortar 27 cubic feet make 1 load, which on common occasions contains half a hundred of lime with a proportional quantity of sand. Eleven hundred and thirty-four cubic inches make a hod of mortar; that is, a mass 9 inches wide, 9 inches high, and 14 inches long. Two hods of mortar are nearly equal to half a bushel. The following measures and weights it may be also useful to remember: —

23½ cubic feet of sand = 1 ton; hence 1 cubic foot weighs 95·3 lbs.

17½ cubic feet of clay = 1 ton; hence 1 cubic foot weighs about 130 lbs.

18 cubic feet of common earth = 1 ton; hence 1 cubic foot weighs nearly 124 lbs.

306 cubic feet of brickwork = 13 tons; hence 1 cubic foot is equal to full 95 lbs.

2306. In the measurement of brickwork, from the surface being 272 feet and the standard thickness 1½ brick, it will be immediately seen that nothing more is requisite than, having ascertained the thickness of each part of the work, to reduce it to the standard thickness above stated, and this will be found sufficiently easy in almost all cases. Where, however, this cannot be done, we can always ascertain with sufficient accuracy the cubic contents in feet of any mass of brickwork; and dividing by 306 we have the number of rods.

2307. We here present an illustration in a wall of the most common occurrence (*fig.* 808.), which we will suppose 20 feet long without reference to any wall which might return from it, and thus diminish its length in measuring therewith a *returning wall*. The following is the method of entering and calculating the dimensions.

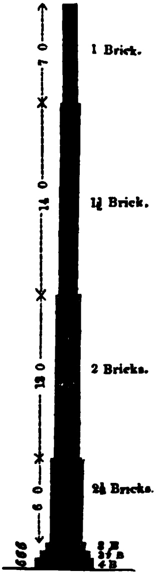

Fig. 808.

	Length multiplied by the Height.	Area.	Number of Bricks in Thickness.	Factors to reduce the Area to Standard of 1½ Brick.	Thickness reduced to 1½ Brick in Feet sup.
Footings 6 courses	20·0 6	10·0	4	2⅔	26·8
	20·0 6	10·0	3½	2⅓	23·4
	20·0 6	10·0	3	2	20·0
Basement wall -	20·0 6·0	120·0	2½	1⅔	200·0
Ground-floor wall	20·0 12·0	240·0	2	1⅓	320·0
One-pair wall -	20·0 14·0	280·0	1½	1	280·0
Two-pair wall -	20·0 7·0	140·0	1	⅔	93·4
					963·4

Therefore the total is 963·4 superficial feet 1½ brick thick, and $\frac{963}{272}$ = 3 rods, 147 feet.

2308. Upon this principle the measuring and estimation of brickwork is conducted, and having the price and quantity of bricks in a rod, and the lime, sand, and labour, which will presently be given, we may come to a pretty accurate knowledge of its value. But there are other articles which will require our attention, to which we shall presently advert. Before proceeding, however, we may as well observe that the above result of 3 rods 147 feet might have been similarly obtained by cubing the mass of brickwork and dividing the whole mass by 306, but with much more labour.

2309. In measuring walls faced with bricks of a superior quality, the area of such facing must be measured, or allowance extra is made in the price per rod of the brickwork.

2310. All apertures and recesses from any of the faces are deducted.

2311. Guaged arches are sometimes deducted and charged separately, sometimes not; but whether deducted or not does not signify, as the extra price must be allowed in the latter case and the whole price in the former. Rubbed and guaged arches, of whatever form, are measured and charged by the superficial foot.

2312. The angles of groins, outside and inside splays, bird's mouths, bull's noses, are measured by the lineal or running foot; but cuttings are measured by the foot superficial. Chimneys are measured solid to allow for the trouble of forming and pargetting the flues. The opening at bottom, however, is to be deducted.

2313. Quarters in bricknogging are measured in, as are all sills, stone strings, and timber inserted in walls. Two inches are also allowed in the height of brickwork for bedding plates if no brickwork be over them.

2314. Ovens, coppers, &c. are measured as solid work, deducting only the ash holes; but all fire stone, Welsh lumps, tiles, &c., though measured alone, are not to be deducted out of the brickwork. Pointing, colouring, &c. to fronts, is measured by the foot superficial. Plantilie creesing by the foot lineal.

To estimate the value of a rod of brickwork, the method is as under: —

	£	s.	d.
4500 stocks, at per thousand - - - - - -	0	0	0
1½ hundred of lime = 37½ striked bushels containing 27 feet cube to the hundred - - - - - - - -	0	0	0
2 loads of sand - - - - - - - -	0	0	0
Labour and scaffolding - - - - - - -	0	0	0
	0	0	0
Per cent. profit - - - - - -	0	0	0
Per rod - - - - - - -	0	0	0

2315. In measuring and estimating all sorts of artificers' works, the method usually adopted for saving labour in making out the account is to arrange in separate columns each sort of work, and then to add them up and carry the total to the bill. In brickwork, where walls are of different thicknesses, these with their deductions are arranged in separate columns, and then all are reduced to the standard thickness.

2316. The common measure for tiling is a square of 10 feet, containing therefore 100 feet superficial. Claims are made for the eaves to the extent of 6 inches; but in pantiling this ought not to be allowed, as a claim not founded in justice, though custom is pleaded for it.

2317. The following table shows the number of bricks necessary for constructing any number of superficial feet of walling from 1 to 90,000, and from half a brick to 2½ bricks thick; and thence, by addition only, to any thickness or number required, at the rate of 4500 bricks to a reduced rod. Thus, if it be required to find the number of bricks wanted to build a piece of work containing 756 feet super. of walling 1½ brick thick, we find by inspection for 700 feet 11580 bricks; for 50 feet, 827 bricks; and for 6 feet, 99 bricks; in all, 11580 + 827 + 99 = 12506.

TABLE SHOWING THE REQUISITE QUANTITY OF BRICKS FOR A GIVEN SUPERFICIES OF WALLING.

Area of Wall in Feet.	No. of Bricks to Thicknesses of				
	½ Brick.	1 Brick.	1½ Brick.	2 Bricks.	2½ Bricks.
1	5	11	16	22	27
2	11	22	33	44	55
3	16	33	49	66	82
4	22	44	66	88	110
5	27	55	82	110	137
6	33	66	99	132	165
7	38	77	115	154	193
8	44	88	132	176	220
9	49	99	148	198	248
10	55	110	165	220	275
20	110	220	330	441	551
30	165	330	496	661	827

Area of Wall in Feet.	No. of Bricks to Thicknesses of				
	½ Brick.	1 Brick.	1½ Brick.	2 Bricks.	2½ Bricks.
40	220	441	661	882	1102
50	275	551	827	1102	1378
60	330	661	992	1323	1654
70	386	772	1158	1544	1930
80	441	882	1323	1764	2205
90	496	992	1488	1985	2481
100	551	1102	1654	2205	2757
200	1102	2205	3308	4411	5514
300	1654	3308	4963	6617	8272
400	2205	4411	6617	8323	11029
500	2757	5514	8272	11029	13786
600	3308	6617	9926	13235	16544
700	3860	7720	11580	15441	19301
800	4411	8823	13235	17647	22058
900	4963	9926	14889	19852	24816
1000	5514	11029	16544	22058	25753
2000	11029	22058	33088	44117	55147
3000	16544	33088	49632	66176	82720
4000	22058	44117	66176	88235	110294
5000	27573	55147	82720	110294	137867
6000	33088	66176	99264	132352	165441
7000	38602	77205	115803	154411	193014
8000	44117	88235	132352	176470	220588
9000	49632	99264	148896	198529	248161
10000	55147	110294	165441	220588	275735
20000	110294	220588	330882	441176	551470
30000	165441	330882	496323	661764	827205
40000	220588	441176	661764	882352	1102940
50000	275735	551470	827205	1102940	1378675
60000	330882	661764	992646	1323528	1654410
70000	386029	772053	1168087	1544116	1930145
80000	441175	882352	1323528	1704704	2205080
90000	496323	992646	1468969	1985292	2481615

2318. The next table which we submit for use exhibits the number of reduced feet to superficial feet from 1 to 10,000, the thicknesses being from ½ to 2½ bricks.

Area of Wall in superficial Feet.	Reduced Quantity in																			
	½ Brick.				1 Brick.				1½ Brick.				2 Bricks.				2½ Bricks.			
	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.
1	0	0	0	4	0	0	0	8	0	0	1	0	0	0	1	4	0	0	1	8
2	0	0	0	8	0	0	1	4	0	0	2	0	0	0	2	8	0	0	3	4
3	0	0	1	0	0	0	2	0	0	0	3	0	0	0	4	0	0	0	5	0
4	0	0	1	4	0	0	2	8	0	0	4	0	0	0	5	4	0	0	6	8
5	0	0	1	8	0	0	3	4	0	0	5	0	0	0	6	8	0	0	8	4
6	0	0	2	0	0	0	4	0	0	0	6	0	0	0	8	0	0	0	10	0
7	0	0	2	4	0	0	4	8	0	0	7	0	0	0	9	4	0	0	11	8
8	0	0	2	8	0	0	5	4	0	0	8	0	0	0	10	8	0	0	13	4
9	0	0	3	0	0	0	6	0	0	0	9	0	0	0	12	0	0	0	15	0
10	0	0	3	4	0	0	6	8	0	0	10	0	0	0	13	4	0	0	16	8
11	0	0	3	8	0	0	7	4	0	0	11	0	0	0	14	8	0	0	18	4
12	0	0	4	0	0	0	8	0	0	0	12	0	0	0	16	0	0	0	20	0
13	0	0	4	4	0	0	8	8	0	0	13	0	0	0	17	4	0	0	21	8
14	0	0	4	8	0	0	9	4	0	0	14	0	0	0	18	8	0	0	23	4
15	0	0	5	0	0	0	10	0	0	0	15	0	0	0	20	0	0	0	25	0
16	0	0	5	4	0	0	10	8	0	0	16	0	0	0	21	4	0	0	26	8
17	0	0	5	8	0	0	11	4	0	0	17	0	0	0	22	8	0	0	28	4

Area of Wall in superficial Feet.	Reduced Quantity in																			
	½ Brick.				1 Brick.				1½ Brick.				2 Bricks.				2½ Bricks.			
	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.	Rods.	qrs.	ft.	in.
18	0	0	6	0	0	0	12	0	0	0	18	0	0	0	24	0	0	0	30	8
19	0	0	6	4	0	0	12	8	0	0	19	0	0	0	25	4	0	0	31	8
20	0	0	6	8	0	0	13	4	0	0	20	0	0	0	26	8	0	0	33	4
21	0	0	7	0	0	0	14	0	0	0	21	0	0	0	28	0	0	0	35	0
22	0	0	7	4	0	0	14	8	0	0	22	0	0	0	29	4	0	0	36	8
23	0	0	7	8	0	0	15	4	0	0	23	0	0	0	30	8	0	0	38	4
24	0	0	8	0	0	0	16	0	0	0	24	0	0	0	32	0	0	0	40	0
25	0	0	8	4	0	0	16	8	0	0	25	0	0	0	33	4	0	0	41	8
26	0	0	8	8	0	0	17	4	0	0	26	0	0	0	34	8	0	0	43	0
27	0	0	9	0	0	0	18	0	0	0	27	0	0	0	36	0	0	0	45	4
28	0	0	9	4	0	0	18	8	0	0	28	0	0	0	37	4	0	0	46	8
29	0	0	9	8	0	0	19	4	0	0	29	0	0	0	38	8	0	0	48	4
30	0	0	10	0	0	0	20	0	0	0	30	0	0	0	40	0	0	0	50	0
31	0	0	10	4	0	0	20	8	0	0	31	0	0	0	41	4	0	0	51	8
32	0	0	10	8	0	0	21	4	0	0	32	0	0	0	42	8	0	0	53	4
33	0	0	11	0	0	0	22	0	0	0	33	0	0	0	44	0	0	0	55	0
34	0	0	11	4	0	0	22	8	0	0	34	0	0	0	45	4	0	0	56	8
35	0	0	11	8	0	0	23	4	0	0	35	0	0	0	46	8	0	0	58	4
36	0	0	12	0	0	0	24	0	0	0	36	0	0	0	48	0	0	0	60	0
37	0	0	12	4	0	0	24	8	0	0	37	0	0	0	49	4	0	0	61	8
38	0	0	12	8	0	0	25	4	0	0	38	0	0	0	50	8	0	0	63	4
39	0	0	13	0	0	0	26	0	0	0	39	0	0	0	52	0	0	0	65	0
40	0	0	13	4	0	0	26	8	0	0	40	0	0	0	53	4	0	0	66	8
41	0	0	13	8	0	0	27	4	0	0	41	0	0	0	54	8	0	1	0	4
42	0	0	14	0	0	0	28	0	0	0	42	0	0	0	56	0	0	1	2	0
43	0	0	14	4	0	0	28	8	0	0	43	0	0	0	57	4	0	1	3	8
44	0	0	14	8	0	0	29	4	0	0	44	0	0	0	58	8	0	1	5	4
45	0	0	15	0	0	0	30	0	0	0	45	0	0	0	60	0	0	1	7	0
46	0	0	15	4	0	0	30	8	0	0	46	0	0	0	61	4	0	1	8	8
47	0	0	15	8	0	0	31	4	0	0	47	0	0	0	62	8	0	1	10	4
48	0	0	16	0	0	0	32	0	0	0	48	0	0	0	64	0	0	1	12	0
49	0	0	16	4	0	0	32	8	0	0	49	0	0	0	65	4	0	1	13	8
50	0	0	16	8	0	0	33	4	0	0	50	0	0	0	66	8	0	1	15	4
60	0	0	20	0	0	0	40	0	0	0	60	0	0	1	12	0	0	1	32	0
70	0	0	23	4	0	0	46	8	0	1	2	0	0	1	25	4	0	1	48	8
80	0	0	26	8	0	0	53	4	0	1	12	0	0	1	38	8	0	1	65	4
90	0	0	30	0	0	0	60	0	0	1	22	0	0	1	52	0	0	2	14	0
100	0	0	33	4	0	0	66	8	0	1	32	0	0	1	65	4	0	2	30	8
200	0	0	66	8	0	1	65	4	0	2	64	0	0	3	62	8	1	0	61	4
300	0	1	32	0	0	2	64	0	1	0	28	0	1	1	60	0	1	3	24	0
400	0	1	65	4	0	3	62	8	1	1	60	0	1	3	57	4	2	1	54	8
500	0	2	30	8	1	0	61	4	1	3	24	0	2	1	54	8	3	0	17	4
600	0	2	64	0	1	1	60	0	2	0.	56	0	2	3	52	0	3	2	48	0
700	0	3	29	4	1	2	58	8	2	2	20	0	3	1	49	4	4	1	10	8
800	0	3	62	8	1	3	57	4	2	3	52	0	3	3	46	8	4	3	41	4
900	1	0	28	0	2	0	56	0	3	1	16	0	4	1	44	0	5	2	4	0
1000	1	0	61	4	2	1	54	8	3	2	48	0	4	3	41	4	6	0	34	8
2000	2	1	54	8	4	3	41	4	7	1	28	0	9	3	14	8	12	1	1	4
3000	3	2	48	0	7	1	28	0	11	0	8	0	14	2	46	0	18	1	36	0
4000	4	3	41	4	9	3	14	8	14	2	56	0	19	2	29	4	24	2	2	8
5000	6	0	34	8	12	1	1	4	18	1	36	0	24	2	2	8	30	2	37	4
6000	7	1	28	0	14	2	56	0	22	0	16	0	29	1	44	0	36	3	4	0
7000	8	2	21	4	17	0	42	8	25	2	64	0	34	1	17	4	42	3	38	8
8000	9	3	14	8	19	2	29	4	29	1	44	0	39	0	58	8	49	0	5	4
9000	11	0	8	0	22	0	16	0	33	0	24	0	44	0	32	0	55	0	40	0
10000	12	1	1	4	24	2	2	8	36	3	4	0	49	0	5	4	61	1	6	8

2319. The following table exhibits the value of a rod of brickwork (allowing 4500 bricks to a rod) at the prices from 30*s.* to 60*s.* per thousand for the bricks, and for labour, mortar, and scaffolding the several sums of 3*l.* 5*s.*, 3*l.* 10*s.*, 3*l.* 15*s.*, 4*l.*, 4*l.* 5*s.*, and 4*l.* 10*s.* per rod.

Bricks per Thousand.	Labour, Mortar, &c. per Rod, 3*l.* 5*s.*			Labour, Mortar, &c. per Rod, 3*l.* 10*s.*			Labour, Mortar, &c. per Rod, 3*l.* 15*s.*			Labour, Mortar, &c. per Rod, 4*l.*			Labour, Mortar, &c. per Rod, 4*l.* 5*s.*			Labour, Mortar, &c. per Rod, 4*l.* 10*s.*		
s.	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
30	10	0	0	10	5	0	10	10	0	10	15	0	11	0	0	11	5	0
32	10	9	0	10	14	0	10	19	0	11	4	0	11	9	0	11	14	0
34	10	18	0	11	3	0	11	8	0	11	13	0	11	18	0	12	3	0
36	11	7	0	11	12	0	11	17	0	12	2	0	12	7	0	12	12	0
38	11	16	0	12	1	0	12	6	0	12	11	0	12	16	0	13	1	0
40	12	5	0	12	10	0	12	15	0	13	0	0	13	5	0	13	10	0
42	12	14	0	12	19	0	13	4	0	13	9	0	13	14	0	13	19	0
44	13	3	0	13	8	0	13	13	0	13	18	0	14	3	0	14	8	0
46	13	12	0	13	17	0	14	2	0	14	7	0	14	12	0	14	17	0
48	14	1	0	14	6	0	14	11	0	14	16	0	15	1	0	15	6	0
50	14	10	0	14	15	0	15	0	0	15	5	0	15	10	0	15	15	0
52	14	19	0	15	4	0	15	9	0	15	14	0	15	19	0	16	4	0
54	15	8	0	15	13	0	15	18	0	16	3	0	16	8	0	16	13	0
56	15	17	0	16	2	0	16	7	0	16	12	0	16	17	0	17	2	0
58	16	6	0	16	11	0	16	16	0	17	1	0	17	6	0	17	11	0
60	16	15	0	17	0	0	17	5	0	17	10	0	17	15	0	18	0	0

2320. The following is a table of the decimal parts of a rod of reduced brickwork.

Feet.	Dec. Parts.	Feet.	Dec. Parts.	Feet.	Dec. Parts.	Feet.	Dec. Parts.	Feet.	Dec. Parts.
1	·00367	41	·15073	81	·29779	121	·44485	161	·59191
2	·00735	42	·15441	82	·30147	122	·44852	162	·59559
3	·01102	43	·15809	83	·30515	123	·45220	163	·59926
4	·01470	44	·16176	84	·30882	124	·45588	164	·60294
5	·01838	45	·16544	85	·3125	125	·45956	165	·60662
6	·02206	46	·16912	86	·31617	126	·46323	166	·61029
7	·02573	47	·17279	87	·31985	127	·46691	167	·61397
8	·02941	48	·17647	88	·32353	128	·47059	168	·61765
9	·03309	49	·18015	89	·32720	129	·47426	169	·62132
10	·03676	50	·18382	90	·33088	130	·47794	170	·625
11	·04044	51	·1875	91	·33456	131	·48162	171	·62867
12	·04412	52	·19117	92	·33823	132	·48529	172	·63235
13	·04779	53	·19485	93	·34191	133	·48897	173	·63604
14	·05147	54	·19852	94	·34559	134	·49265	174	·63971
15	·05515	55	·20221	95	·34926	135	·49632	175	·64338
16	·05882	56	·20588	96	·35294	136	·5	176	·64706
17	·0625	57	·20956	97	·35662	137	·50637	177	·65073
18	·06617	58	·21323	98	·36029	138	·50735	178	·65441
19	·06985	59	·21691	99	·36397	139	·51102	179	·65809
20	·07353	60	·22059	100	·36765	140	·51470	180	·66176
21	·07721	61	·22426	101	·37132	141	·51838	181	·66544
22	·08088	62	·22794	102	·375	142	·52206	182	·66912
23	·08456	63	·23162	103	·37867	143	·52573	183	·67279
24	·08823	64	·23529	104	·38235	144	·52941	184	·67647
25	·09191	65	·23897	105	·38604	145	·53309	185	·68015
26	·09559	66	·24265	106	·38970	146	·53676	186	·68382
27	·09926	67	·24632	107	·39338	147	·54044	187	·6875
28	·10294	68	·25	108	·39706	148	·54412	188	·69117
29	·10662	69	·25367	109	·40073	149	·54779	189	·69485
30	·11029	70	·25735	110	·40441	150	·55147	190	·69853
31	·11397	71	·26103	111	·40809	151	·55515	191	·70221
32	·11765	72	·26470	112	·41176	152	·55882	192	·70588
33	·12132	73	·26838	113	·41544	153	·5625	193	·70956
34	·125	74	·27206	114	·41912	154	·56617	194	·71323
35	·12867	75	·27573	115	·42279	155	·56985	195	·71691
36	·13235	76	·27941	116	·42647	156	·57353	196	·72059
37	·13604	77	·28309	117	·43015	157	·57721	197	·72426
38	·13970	78	·28676	118	·43382	158	·58088	198	·72794
39	·14338	79	·29044	119	·4375	159	·58456	199	·73162
40	·14706	80	·29412	120	·44117	160	·58823	200	·73529

Feet.	Dec. Parts.	Feet.	Dec. Parts.	Feet.	Dec. Parts.	Feet.	Dec. Parts.	Feet.	Dec. Parts.
201	·73897	216	·79412	231	·84926	245	·90073	259	·95221
202	·74265	217	·79779	232	·85294	246	·90441	260	·95588
203	·74632	218	·80147	233	·85662	247	·90809	261	·95956
204	·75	219	·80515	234	·86029	248	·91176	262	·96323
205	·75367	220	80882	235	·86397	249	·91544	263	·96691
206	·75735	221	·8125	236	·86765	250	·91912	264	·97059
207	·76103	222	·81617	237	·87132	251	·92279	265	·97426
208	·76470	223	·81985	238	·875	252	·92647	266	·97794
209	·76838	224	·82353	239	·87867	253	·93015	267	·98162
210	·77206	225	·82721	240	·88235	254	·93382	268	·98529
211	·77573	226	·83088	241	·88604	255	·9375	269	·98897
212	·77941	227	·83456	242	·88970	256	·94117	270	·99265
213	·78309	228	·83823	243	·89338	257	·94485	271	·99632
214	·78676	229	·84191	244	·89706	258	·94853	272	1·00000
215	·79044	230	·84559						

2321. The subjoined table shows the number of plaintiles or pantiles required to cover any area from 1 to 10,000 feet.

Feet superficial.	Plaintiles.			Pantiles.		
	Gauges.			Gauges.		
	6 inches.	6½ inches.	7 inches.	11 inches.	12 inches.	13 inches.
1	7½	7	6½	1⅔	1½	1⅓
2	15	14	13	3⅓	3	2⅔
3	22½	21	19½	5	4½	4
4	30	28	26	6⅔	6	5⅓
5	37½	35	32½	8⅓	7½	6⅔
6	45	42	39	10	9	8
7	52½	49	45½	11⅔	10½	9⅓
8	60	56	52	13⅓	12	10⅔
9	67½	63	58½	15	13½	12
10	75	70	65	16⅔	15	13⅓
20	150	140	130	33⅓	30	26⅔
30	225	210	195	50	45	40
40	300	280	260	66⅔	60	53⅓
50	375	350	325	83⅓	75	66⅔
60	450	420	390	100	90	80
70	525	490	455	116⅔	105	93⅓
80	600	560	520	133⅓	120	106⅔
90	675	630	585	150	135	120
100	750	700	650	166⅔	150	133⅓
200	1500	1400	1300	333⅓	300	266⅔
300	2250	2100	1950	500	450	400
400	3000	2800	2600	666⅔	600	533⅓
500	3750	3500	3250	833⅓	750	666⅔
600	4500	4200	3900	1000	900	800
700	5250	4900	4550	1166⅔	1050	933⅓
800	6000	5600	5200	1333⅓	1200	1066⅔
900	6750	6300	5850	1500	1350	1200
1000	7500	7000	6500	1666⅔	1500	1333⅓
2000	15000	14000	13000	3333⅓	3000	2666⅔
3000	22500	21000	19500	5000	4500	4000
4000	30000	28000	26000	6666⅔	6000	5333⅓
5000	37500	35000	32500	8333⅓	7500	6666⅔
6000	45000	42000	39000	10000	9000	8000
7000	52500	49000	45500	11666⅔	10500	9333⅓
8000	60000	56000	52000	13333⅓	12000	10666⅓
9000	67500	63000	58500	15000	13500	12000
10000	75000	70000	65000	16666⅔	15000	13333⅓

The use of the foregoing tables it can scarcely be necessary to explain. They are such as to indicate, on inspection, their value; and we shall therefore leave them without further comment for their application.

2322. When work is performed by the day, or the materials used are to be numbered, as ofttimes necessarily occurs, fire bricks, red rubbers, best marle stocks for cutters, second best ditto, pickings, common bricks, place bricks, paving bricks, kiln-burnt bricks, and Dutch clinkers are charged by the thousand.

2323. Red rubbers, kiln and fire-burnt bricks, are also charged by the hundred. Foot tiles and ten inch tiles are charged either by the thousand or hundred.

2324. Sunk foot tiles and ten-inch tiles with five holes, now never used in the south of England, are charged by the piece.

2325. Pantiles, plaintiles, and nine-inch tiles are charged by the thousand.

2326. Oven and Welsh oven tiles, Welsh fire lumps, fire bricks, and chimney pots are also sold by the piece.

2327. Sand, clay, and loam are charged by the load; lime sometimes by the hundred weight; but the *hundred* of 100 pecks is the more usual measure in and about the metropolis. Dutch terras is charged by the bushel, which is also sometimes the measure of lime. Parker's cement is similarly charged.

2328. Pantile and plaintile laths are charged by the bundle or load; hair and mortar by the load; hip hooks and T tiles by the piece.

2329. Neither here, nor in the following pages, is it intended to convey to the reader more than the principles on which an estimate is founded. The prices of materials are in a state of constant fluctuation; and though when we come to the consideration of the prices of joiner's work, we intend, from the ingenious computations of Mr. Peter Nicholson, to give something approaching a constant value from the known performance of a good workman, it is to be recollected by the student, that cases so vary as to make it impossible to give a list of prices and value, that would be of any value at the period of a month from the time of his reading this paragraph. The details of prices he must constantly watch if he intends to do justice to his employer.

CARPENTRY AND JOINERY.

2330. The works of the CARPENTER are the preparation of piles, sleepers, and planking, and other large timbers, formerly much, but now rarely, used in foundations; the centering on which vaults are turned; wall plates, lintels, and bond timbers; naked flooring, quarter partitions, roofing, battening to walls, ribbed ceilings for the formation of vaulting coves, and the like in lath and plaster, posts, &c.

2331. In large measures, where the quantity of materials and workmanship is uniform, the articles are usually measured by the square of 100 feet. Piles should be measured by the foot cube, and the driving by the foot run according to the quality of the ground into which they are driven. Sleepers and planking are measured and estimated by the foot, yard, or the square.

2332. Plain centering is measured by the square; but the ribs and boarding, being different qualities of work, should be taken separately. The dimensions are obtained by girting round the arch, and multiplying by the length. Where groins occur, besides the measurement as above, the angles must be measured by the foot run, that is, the ribs and boards are to be measured and valued separately, according to the exact superficial contents of each, and the angles by the linear foot, for the labour in fitting the ribs and boards, and waste of wood.

2333. Wall plates, bond timbers, and lintels are measured by the cubic foot, and go under the denomination of *fir in bond*.

2334. In the measurement and valuation of naked flooring, we may take it either by the square or the cube foot. To form an idea of its value, it is to be observed, that in equal cubic quantities of small and large timbers the latter will have more superficies than the former, whence the saving is not in proportion to the solid contents; and the value, therefore, of the workmanship will not be as the cubic quantity. The trouble of moving timbers increases with their weight, hence a greater expenditure of time; which, though not in an exact ratio with the solid quantity, will not be vastly different, their sections not varying considerably in their dimensions. As the value of the saving upon a cube foot is comparatively small to that of the work performed by the carpenter, the whole cost of labour and materials may be ascertained with sufficient accuracy when the work is uniform.

2335. When girders occur in naked flooring, the uniformity of the work is thereby interrupted by the mortices and tenons which become necessary; thus the amount arising from the cubic quantity of the girders would not be sufficient at the same rate per foot as is put on the other parts, not only because of the difference of the size, but because of the mortices which are cut for the reception of the tenons of the binding joists. Hence, for valuing the labour and materials, the whole should be measured and valued by the cubic quantity, and an additional rate must be put upon every solid foot of the girders; or, if the binding joists be not inserted in the girders at the usual distances, a fixed price must be put upon every mortice and tenon in proportion to their size. The binding joists are not unfrequently pulley or chase-morticed for the reception of the ceiling joists; sometimes they are notched to receive the bridging joists on them, and they should therefore be classed by themselves at a larger price per foot cube, or at an additional price for the workmanship, beyond common joisting. All these matters must be in proportion to the description of the work, whether the ceiling joists be put in with pulley mortices and tenons, or the bridgings notched or adzed down.

2336. Partitions may be measured and estimated by the cube foot; but the sills, top pieces, and door heads should be measured by themselves, according to their cubic contents, at a larger price; because not only the uniform solidity, but the uniform quantity, of the workmanship is interrupted by them. The braces in trussed partitions are to be taken by the foot cube at a larger price than the common quartering, on account of the trouble of fitting the ends of the uprights upon their upper and lower sides, and of forming the abutments at the ends.

2337. All the timbers of roofing are to be measured by the cubic foot, and classed according to the difficulty of execution, or the waste that occurs in performing the work. Common rafters, as respects labour, are rated much the same as joists or quarters; purlins, which require trouble in fitting, are worth more, because on them are notched down the common rafters. The different parts of a truss should, to come accurately at the true value, be separately taken, and the joggles also separately considered, including the tenons at the ends of the struts; morticing tie beams and principals, forming the tenons of the truss posts, morticing and tenoning the ends of the tie beams and principals, is in another class. The strapping is paid for according to the number of the bolts. Common or bridging rafters' feet are also to be considered; the size and description of the work being always matter for the consideration of the architect.

2338. It is usual and fair to measure the battening of walls by the square, according to the dimensions and distances of the battening.

2339. Ribbed ceilings are taken by the cubic quantity of timber they contain, making due allowance for the waste of stuff, which is often considerable. The price of their labour is to be ordered by the nature of the work, and the cubic quantity they contain.

2340. Trimmers and trimming joists are so priced as to include the mortices and tenons they contain, and also the tenons at the extremities of the trimmers. But to specify all the methods required of ascertaining the value of each species of carpenter's work would be impossible, with any respect to our limits. They must be learned by observation; all we have to do is with the principles on which measuring and estimating is conducted.

2341. When the *carcass* of the building is completed, before laying the floors or lathing the work for receiving the plastering, the timbers should be measured, so that the scantlings may be examined and proved correct, according to the specification; and in this, as a general rule, it is to be remembered that all pieces having tenons are measured to their extremities, and that such timbers as girders and binding joists lie at least 9 inches at their ends into the walls, or ⅓ of the wall's thickness, where it exceeds 27 inches. In the measurement of bond timber and wall plates, the laps must be added to the net lengths. If a necessity occur for cutting parallel pieces out of truss posts (such as king or queen-posts), when such pieces exceed 2 feet 6 inches in length, and 2½ inches in thickness, they are considered as pieces fit for use, deducting 6 inches as waste from their lengths.

2342. The boarding of a roof is measured by the square, and estimated according to its thickness, and the quantity of boards and the manner in which they are jointed.

2343. Where the measurement is for labour and materials, the best way is, first, to find the cubical contents of a piece of carpentry, and value it by the cubic foot, including the prime cost, carting, sawing, waste, and carpenter's profit, and then to add the price of the labour, properly measured, as if the journeyman were to be paid. It is out of the question to give a notion of any fixed value, because it must necessarily vary, as do materials and labour; hence no tables or price-books are ever to be depended upon; they gull the unwary, and mislead the amateur who consults them. The only true method of forming a proper estimate is dependent on the price of timber and deals, for which general tables may be formed, and some will be presently given.

2344. It is, perhaps, unnecessary to repeat that a load of fir timber contains 50 cube feet: if, then, we know the price of the load in the timber merchant's yard, we may approximate the value of a cube foot as under. We will suppose the price to be, at the moment of estimating, 4*l.* 10*s.* per load. We shall then have —

	£	s.	d.
Prime cost of a load of fir - - - - - -	4	10	0
Suppose the cartage (dependent on distance) - - - -	0	5	0
Sawing into necessary scantlings - - - - -	0	10	0
	5	5	0
Waste in converting equal to 5 feet, at 2$\frac{1}{10}$ s. per foot, the load being 105s.	0	10	6
	5	15	6
20 per cent. profit on *5l.* 15*s.* 6*d.* -	1	3	0
	£6	18	6

2345. Now, $\frac{6l.\ 18s.\ 6d.}{50}$ = 2·77 shillings, or 2 shillings and 9 pence and nearly 1 farthing per foot cube.

2346. It is only in this way that we can arrive at the value of work; and it is much to be regretted that from no species of labour of the carpenter have been formed tables capable of furnishing such a set of constants as would, by application to the rate of a journeyman's wages, form factors, or, in other words, furnish data for a perpetual price-book. As we have before hinted, the best of the price-books that have ever been published are useless as guides to the value of work. The method of lumping work by the square is as much as possible to be avoided, unless the surfaces be of a perfectly uniform description of workmanship; as, for instance, in hipped roofs, the principal trouble is at the hips, in fitting the jack rafters, which are fixed at equal distances thereon; hence such a price may be fixed for the cubic quantity of hips and valleys as will pay not only for them, but also for the trouble of cutting and fixing the jack rafters. Such parts, indeed, as these should be separately classified; but the analysis of such a subject requires investigation of enormous labour; and as it must depend on the information derived from the practical carpenter, is, we fear, not likely to be soon, if ever, accomplished.

2347. Mr. Peter Nicholson, a gentleman to whom the architect as well as the practical man are more indebted than to any other author on this subject, is the only person who has attempted to promulgate a system founded on the scientific basis to which we have just alluded; and we have much pleasure in here alluding to the value of his labour, and of placing before the reader the extent to which he carried it, regretting much that he did not further pursue an investigation, which we have carried to a greater extent, though not now so complete as we could have wished.

2348. It is manifest that if the average time of executing each species of work were known, no difficulty could exist in fixing uniform rates of charge for it; but, as we have observed, the parties who could best instruct us on the subject are those most interested in withholding such information as would be required for the purpose. We shall now proceed to the question, premising that, for the present, we are only dealing with the cost of labour, that of the materials being a simple affair, as we have already seen in the case of ascertaining the value of a cubic foot of fir, and as we shall hereafter see in ascertaining the value of superficial feet of deals of any thickness.

2349. In the subjoined tables, the price is represented by the days, or decimal parts of a day, in which one man can perform the quantity of that sort of work, against which such price is affixed. Hence, knowing the rate per day of such man's wages, it forms a factor by which the value of the labour of such quantity of work will be estimated. We begin by centering.

Centering.

For plain cylindric vaults, fixed per square - -	2·033 days.
For groins of cylindric vaults, fixed per foot super. - -	·057
For guaged brickwork, per foot super. - - -	·073
For brick trimmers bridgewise, per foot super. - -	·041
For coach-head trimmers, per foot super. - - -	·057
For apertures, per foot run - - - - - -	·02

2350. To apply this to practice, we will take the first article in the table, that of the centering of a cylindric vault, a square whereof, we see, will occupy a man 2·033 days to make and fix. Now, supposing such man's wages to be *5s.* per diem, we have only to multiply 2·033 by *5s.* = 10·165, or nearly 10*s.* 2*d.* for a square of such work. The other items being similarly used, will give the results whereof we are in search.

The next table is one composed of several miscellaneous articles, and is as follows: —

Fir in bond and wood bricks, at per foot run - - -	·008 day.
Fir in templates, lintels, and turning pieces, at per foot run -	·025
Planing fir, from the saw, per foot super. - - -	·017
Rebating fir up to 2 in. by ¾ - - - - -	·025
Rebating fir from 2 in. by ¾ to 3 in. by 1¼ - - -	·041

Single beading, up to ¾ inch	·008 day.
Single quirk beading, from ¾ inch to 1¼	·012
Return beads, worth double.	

The next table is for quarter partitions: —

Common 4-inch, per square	1·033 days.
Common 5-inch, per square	1·113
Common 6-inch, per square	1·307
Common 6-inch, circular plan, per square	1·888
Common trussed frame, with king-post, per square	1·743
Common trussed frame, with king and queen-posts, per square	2·226

The subjoined is a table for naked flooring: —

Ceiling floor, framed with tie beams, binding and ceiling joists, fixed per square	1·355 days.
Ceiling floor, with tie beams and ceiling joists only, fixed per square	1·065
Ceiling joists only, fixed per square	·646
Single-framed floor, trimmed to chimney, and well holes less than 9 inches deep, fixed per square	1·355
The same, above 9 inches deep, fixed per square	1·646
The same, if trimmed to party walls, add extra per square, ·388.	
Single-framed floor, with one girder, fixed per square	1·936
Strutting to be paid for extra.	
Single-framed floor-case and tail-bays, fixed per square	2·130
For every extra bay, add per square, ·484.	
Framed floors, with girders, binding and ceiling joists, fixed per square	3·581
Ground joists, bedded, fixed per square	·775
Ground joists, framed to chimneys, fixed per square	·968
Ground joists, pinned down on plates and framed to chimneys, fixed per square	1·065
Girders reversed and bolted, per foot run	·097
Truss girder braces, 4 by 4, per foot run	·194
If any of the above works be executed in oak, add one third.	

The following table is for roofing of various sorts: —

Common shed roofing, one story high, fixed per square		·968
Common shed roofing, two stories high, fixed per square		1·033
Common shed roofing, three stories high, fixed per square		1·113
Single span roofing, one story high, fixed per square		1·065
Single span roofing, two stories high, fixed per square		1·113
Single span roofing, three stories high, fixed per square		1·210
If the above are with purlins, add ·194 per square.		
If purlins are framed diagonally, add ·388 per square.		
Hips and valleys, per foot run		·08
In common kerb roofing, add extra per square, when one side is kerbed	·194	
When three sides	·357	
When four sides	·516	
Girt of roofing, with framed principals, collar beams, and purlins, fixed per square		2·323
Framed with principals, beams, king-posts, purlins, and common rafters, fixed per square		3·484
If the principals and rafters are framed flush, and the purlins housed in, add ·387 day to the above.		
Framed with principals, beams, king-posts, queen-posts, and common rafters, three stories, fixed per square		4·549 days.
The same, four stories, fixed per square		4·84
Hips and valleys, per foot run		·145
Hip and ridge rolls, fixed in iron, per foot run		·048
Bedded plates to common span roofing, per foot run		·008
Bedded plates to framed roofing, as above, per foot run		·028
Diagonal and dragon pieces, per foot run		·065
Angular ties and struts, per foot run		·032
Rafters' feet and eaves bond, per foot run		·032

The table for guttering is as follows: —

Inch or inch and quarter deal and bearers, including 6-inch layer board, per foot super.	·057
The same in kerb roofs, per foot super.	·073

For furrings and battenings, table as follows: —

If the stuff be ¾ by 1¼ inch, fixed per square	·872 day.
If it has also to be cut out, add ·146 per square.	
Battenings with quarters, 3 by 2 inches, fixed per square	·92
Battenings to quarters, 3 by 2 inches to window piers, fixed per square	1·355
If the battens be fixed to plugs, add ·29 per square.	
When any of the above are circular on the plan, half as much more must be added to the price of the work.	

Table for bracketing, including plugging, is as under: —

To straight cornices, fixed per foot super.	·089 day.
To coved straight cornices, fixed per foot super.	·065
If circular on the plan, add one half more.	
To groins in passages less than 4 feet wide, fixed per foot super.	·162
To the same above 4 feet, fixed per foot super.	·121

2351. The works of the Joiner consist in the preparation of boarding, which is measured and estimated by the foot superficial. Of this there are many varieties; as, edges shot; edges shot, ploughed, and tongued; wrought on one side and edges shot; the same on both sides and edges shot; wrought on both sides and ploughed and tongued. Boards keyed and clamped; mortice clamped, and mortice and mitre clamped. The value per foot increases according to the thickness of the stuff. When longitudinal joints are glued, an addition per foot is made; and if feather-tongued, still more.

2352. The measurement and estimation of floors is by the square, the price varying as the surface is wrought or plain; the method of connecting the longitudinal and heading joints, and also on the thickness of the stuff; as well as on the circumstance of the boards being laid one after another or folded; or whether laid with boards, battens, wainscot, or other wood. Skirtings are measured by the foot super., according to their position, as whether level, raking, or ramping. Also on the manner of finishing them, as whether plain, torus, rebated, scribed to floors or steps, or whether straight or circular on the plan.

2353. The value of every species of framing must depend on the thickness of the stuff employed, whether it is plain or moulded; and if the latter, whether the mouldings be struck on the solid, or laid in; whether mitred or scribed, and upon the number of panels in a given height and breadth, and also on the form of the plan.

2354. Wainscotings, window-linings, as backs and elbows; door linings, such as jambs and sofites; back linings, partitions, doors, shutters, and the like, are all measured and valued by the foot super. The same mode is applied to sashes and their frames, either together or separately.

2355. Skylights, the prices whereof depend on their plans and elevations, are also measured by the foot super. Framed grounds, by the foot run.

2356. The value of dado, which varies as the plan is straight or circular, or being level or inclined, is measured by the foot super.

2357. In the measurement of staircases, the risers, treads, carriages, and brackets are, after being classed together, measured by the foot super., and the string board is sometimes included. The value varies as the steps may be flyers or winders, or from the risers being mitred into the string board, the treads dovetailed for balusters and the nosings returned, or whether the bottom edges of the risers are tongued into the step. The curtail step is valued by itself, and returned nosings are sometimes valued at the piece; and if they are circular on the plan, they are charged at double the price of straight ones. The handrail, whose value depends upon the materials and diameter of the well hole, or whether ramped, swan-necked, level, circular, or wreathed; whether got out of the solid, or in thicknesses glued up together, is measured by the foot run. The scroll is charged by itself, as is the making and fixing each joint screw, and 3 inches of the straight part at each end of the wreath is measured in. The deal balusters, as also the iron ones and the iron columns to curtail, housings to steps and risers, common cut brackets, square and circular on the plan, together with the preparing and fixing, are valued all by the piece. Extra sinking in the rail for iron balusters is valued by the foot run, the price depending on the rail as being straight, circular, wreathed, or ramped. The string board is measured by the foot super., and its value is greater or less as it is moulded, straight, or wreathed, or according to the method in which the wreathed string is constructed by being properly backed upon a cylinder.

2358. The shafts of columns are measured by the foot super., their value depending upon the diameter, or whether it be straight or curved on the side, and upon its being properly glued and blocked. If the columns be fluted, the flutes are taken in linear measure, the price depending on the size of the flutes, whose headings at top and bottom are charged by the piece. Pilasters, straight or curved in the height, are similarly measured, and the price taken by the foot super. In the caps and bases of pilasters, besides the mouldings, the mitres are charged so much each, according to the size.

2359. Mouldings, as in double-face architraves, base and surbase, or straight ones struck by the hand, are valued by the foot super. Base, surbase, and straight mouldings wrought by hand, are generally fixed at the same rate per foot, being something more than double-faced architraves. When the head of an architrave stands in a circular wall, its value is four times that of the perpendicular parts, as well on account of the extra time required to fit it to the circular plan as of the greater difficulty in forming the mitres. So all horizontal mouldings on a circular plan are three or four times the value of those on a straight plan, the trouble being increased as the radius of the circle upon which they are formed diminishes. The housings of mouldings are valued by the piece. The value of mouldings much depends on the number of their quirks, for each whereof the price increases. It will also, of course, depend on the materials of which they are formed, on their running figure, and whether raking or curved.

2360. Among the articles which are to be measured by the lineal foot are beads, fillets, bead or ogee capping, square angle staffs, inch ogees, inch quirk ogee, ovolo and bead, astragals and reeds on doors or shutters, small reeds, each in reeded mouldings, struck by hand up to half an inch, single cornice or architrave, grooved space to let in reeds and grooves. And it must be observed, that in grooving, stops are paid extra; if wrought by hand, still more; and yet more if circular. Besides the foregoing, narrow grounds to skirting, the same rebated or framed to chimneys, are measured by the foot run. Rule joints, cantilevers, trusses, and cut brackets for shelves are charged by the piece.

2361. Water trunks are valued according to their size by the foot run, their hopper heads and shoes being valued by the piece. Moulded weather-caps and joints by the piece. Scaffolding, where extra, must be allowed for. Flooring boards are prepared according to their length, not so much each; the standard width is 9 inches; if they are wider, the rate is increased, each board listing at so much per list. Battens are prepared in the same way, but at a different rate.

2362. The following memoranda are useful in estimating: —

1 hundred (120) 12-feet-3-inch deals, 9 inches wide (each deal containing, therefore, 2 feet 3 inches cube), equal 5⅜ loads of timber.
1 hundred (120) 12-feet-2½-inch deals, 9 inches wide (each deal containing, therefore, 1 foot 10 inches cube), equal 4½ loads of timber.
1 hundred (120) 12-feet-1½-inch deals equal 1 reduced hundred.
1 load of 1½-inch plank, or deals, is 400 feet superficial.
1 load of 2-inch plank, or deals, is 300 feet superficial.
And so on in proportion.
24 loads of 10-feet boards, at a 5-inch guage, will finish one square.
20 loads of 10-feet boards, at a 6-inch guage, will finish one square.
17 loads of 10-feet boards, at a 7-inch guage, will finish one square.
15 loads of 10-feet boards, at an 8 inch guage, will finish one square.
13 loads of 10-feet boards, and 2 ft. 6 in. super., at a 9-inch guage, will finish one square.
12 loads of 10-feet boards, and 2 ft. 6 in. super., at a 10-inch guage, will finish one square.
20 loads of 12-feet boards, at a 5-inch guage, will finish one square.
16 loads of 12-feet boards, at a 6-inch guage, will finish one square.
14 loads of 12-feet boards, at a 7-inch guage, will finish one square.
12 loads of 12-feet boards, and 4 feet super., at an 8-inch guage, will finish one square.
11 loads of 12-feet boards, and 1 foot super., at a 9-inch guage, will finish one square.
10 loads of 12-feet boards, and 1 foot super., at a 10-inch guage, will finish one square.
Battens are 6 inches wide.
Deals are 9 inches wide.
Planks are 11 inches wide.
Feather-edged deals are equal to ¾-inch yellow deals; if white, equal to slit deal.
A reduced deal is 1½ inch thick, 11 inches wide, and 12 feet long.

2363. It may here be useful to advert to the mode of reducing deals to the standard of what is called a reduced deal, which evidently contains 1 ft. 4 in. 6 parts cube, for 12 ft. × 11 in. × 1½ in. = 1 : 4 : 46, or in decimals, 12 ft. × ·91666 ft. × ·125 ft. = 1·375 cube ft. nearly. Hence the divisor 1·375 will serve as a constant for reducing deals of different lengths and thicknesses. Thus let it be required to find how many reduced deals there are in one 14 feet long, 10 inches wide, and 2½ inches thick. Here 14 ft. × ·8333 ft. (or 10 in.) × ·20833 (or 2½ in.) = 2·43042 cube feet, and $\frac{2·43042}{1·375}$ = 1·767 reduced deal.

2364. The table which is now subjoined exhibits the prices of deals and parts thereof calculated from 30*l.* to 95*l.* per hundred, a range of value out of which it can rarely happen that examples will occur, though it has fallen within our own experience during the late war to see the price of deals at a very extraordinary height. This, however, is not likely to happen again.

Price per hundred.	Thickness.	10 feet long each.		12 feet long each.		14 feet long each.		Per foot run.		Per foot super.	
	In.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
£30.	½	1	4¾	1	8	1	11¼	0	2	0	2½
	¾	1	7¼	1	11¼	2	3	0	2¼	0	3
	1	2	0¾	2	5¾	2	10½	0	3	0	3¾
	1¼	2	6½	3	0½	3	6½	0	3½	0	4¾
	1½	2	11¾	3	6¾	4	1¾	0	4¼	0	5½
	2	3	11	4	7	5	4	0	5¼	0	7
	2½	4	8½	5	8¼	6	7½	0	6½	0	8¾
	3	5	5¾	6	7	7	8¼	0	7½	0	10
£35.	½	1	6¾	1	10½	2	2¼	0	2¼	0	3
	¾	1	10¼	2	2¾	2	7¼	0	2½	0	3½
	1	2	4	2	9½	3	3½	0	3¼	0	4¼
	1¼	2	10½	3	5½	4	0¼	0	4	0	5¼
	1½	3	5	4	1	4	9	0	4¾	0	6¼
	2	4	3¾	5	2	6	0¼	0	6	0	8
	2½	5	4¾	6	5¾	7	6¾	0	7½	0	10
	3	6	4¾	7	7½	8	10¾	0	9	0	11¾
£40.	½	1	8¾	2	1	2	5¼	0	2½	0	3¼
	¾	2	0¾	2	5¾	2	10¾	0	3	0	3¾
	1	2	7½	3	2	3	8¼	0	3¾	0	5
	1¼	3	3	3	10¾	4	6½	0	4½	0	6
	1½	3	10	4	7¼	5	4½	0	5½	0	7
	2	4	11¾	5	11¾	6	11¾	0	7	0	9¼
	2½	6	2	7	5	8	8	0	8¾	0	11¼
	3	7	2¾	8	8	10	1½	0	10	1	1¼
£45.	½	1	11	2	3½	2	8	0	2¾	0	3½
	¾	2	3½	2	9	3	2½	0	3¼	0	4¼
	1	2	11¼	3	6¼	4	1¼	0	4	0	5½
	1¼	3	7¼	4	4	5	0½	0	5	0	6½
	1½	4	3¼	5	1½	5	11¾	0	6	0	8
	2	5	7	6	8¼	8	11	0	7¾	0	10¼
	2½	6	11	8	3½	9	8	0	9¼	1	0¾
	3	8	1	9	8½	11	4	0	11¼	1	3
£50.	½	2	1½	2	6	2	11	0	3	0	4
	¾	2	6	3	0	3	6	0	3½	0	4¾
	1	3	2½	3	10¼	4	6	0	4½	0	6
	1¼	3	11¼	4	9	5	6½	0	5½	0	7¼
	1½	4	8½	5	7¾	6	7	0	6½	0	8¾
	2	6	2½	7	5	8	7½	0	8½	0	11½
	2½	7	7¾	9	2	10	8¾	0	11¼	1	2
	3	8	11½	10	9	12	6½	1	0½	1	4½
£55.	½	2	3	2	8½	3	3	0	3¼	0	4¼
	¾	2	8¾	3	3¼	3	9¾	0	3¾	0	5
	1	2	6½	4	2¾	4	11½	0	5	0	6½
	1¼	4	4	5	2½	6	1	0	6	0	8
	1½	5	1¾	6	2¼	7	3½	0	7¼	0	9½
	2	6	8¾	8	1	9	5¼	0	9¼	1	0½
	2½	8	4½	10	10½	11	8½		11¾	1	3½
	3	9	10	11	9½	13	9	1	1¾	1	6¼
£60.	½	2	5	2	11	3	5	0	3½	0	4½
	¾	2	11¼	3	6¼	4	1¼	0	4	0	5½
	1	3	9¼	4	7	5	4¼	0	5¼	0	7
	1¼	4	8½	5	7¾	6	7	0	6½	0	8¾
	1½	5	6¾	6	8¼	7	9¾	0	7¾	0	10¼
	2	7	3½	8	9	10	2½	0	10¼	1	1
	2½	9	1¼	10	11	12	8¾	1	0½	1	4¾
	3	10	8¼	12	10	14	11½	1	2¾	1	7¾
£65.	½	2	7¼	3	1½	3	7¾	0	3½	0	4¾
	¾	3	1¾	3	9½	4	5	0	4½	0	5½
	1	3	11¼	4	11	5	1¾	0	5¾	0	7½
	1¼	5	0¾	6	0¾	7	0¾	0	7	0	9¼
	1½	6	0	7	2½	8	5	0	8¼	0	11
	2	7	9¾	9	4½	10	11¼	0	11	1	2¼
	2½	9	9	11	8¼	13	7¼	1	1½	1	6
	3	11	6¾	13	10½	16	2¼	1	4	1	9½
£70.	½	2	9¼	3	4	3	10¾	0	3¾	0	5¼
	¾	3	4½	4	0½	4	8½	0	4¾	0	6¼
	1	4	4½	5	3	6	1½	0	6	0	8
	1¼	5	5	6	6	7	7	0	7½	0	10
	1½	6	5¾	7	8¾	9	0	0	9	1	0
	2	8	5¾	10	2¼	11	10½	0	11¾	1	3¾
	2½	10	6¾	12	8	14	9½	1	2½	1	7½
	3	12	5	14	11	17	5	1	5	1	11
£75.	½	2	11½	3	6½	4	1½	0	4	0	5½
	¾	3	7¼	4	3¾	5	0¼	0	5	0	6¼
	1	4	8¼	5	7½	6	6¾	0	6½	0	8½
	1¼	5	9¾	6	11¾	8	1¾	0	8	0	10¾
	1½	6	10½	8	3	9	7½	0	9½	1	0¾
	2	9	1¾	10	11¾	12	9¾	1	0¾	1	5
	2½	11	3¾	13	7	15	10¼	1	3¾	1	9
	3	13	3½	15	11½	18	7½	1	6¾	2	0½
£80.	½	3	1½	3	9	4	4½	0	4¼	0	5¾
	¾	3	9¾	4	6¾	5	3¾	0	5¼	0	7
	1	4	11½	5	11½	6	11½	0	6¾	0	9
	1¼	6	1¾	7	4½	8	7¼	0	8½	0	11¼
	1½	7	3¾	8	9¼	9	[illegible]¾	0	10	1	1½
	2	9	7½	11	6½	13	5½	1	1¼	1	5¾
	2½	13	11¼	14	4½	16	9¼	1	4	1	9½
	3	14	2	17	0	19	10	1	7½	2	2½
£85.	½	3	4	3	11½	4	8	0	4½	0	6
	¾	4	0¼	4	10	5	7¾	0	5¼	0	7½
	1	5	3¼	6	3¾	7	4½	0	7½	0	9¾
	1¼	6	6	7	9½	9	1	0	8¾	1	0
	1½	7	9	9	3½	10	10	0	10¾	1	2½
	2	10	2	12	2½	14	3	1	2	1	6¾
	2½	12	8	15	2½	18	0	1	5½	1	11½
	3	14	11½	18	0½	21	0½	1	8¾	2	3¾
£90.	½	3	5¾	4	2	4	10½	0	4¾	0	6½
	¾	4	2¾	5	1	5	11¼	0	5¾	0	7¾
	1	5	6½	6	7¾	7	9	0	7¾	0	10¼
	1¼	6	10¼	8	2¾	9	7¼	0	9½	1	0¾
	1½	8	2½	9	9¾	11	5½	0	11¼	1	3¼
	2	10	9¼	12	11	15	0¾	1	3	1	8
	2½	13	4¾	16	0¾	18	9	1	6½	2	0¾
	3	15	11	19	1	22	3	1	10	2	5½
£95.	½	3	7¾	4	4½	5	1¼	0	5	0	6¾
	¾	4	5½	5	4¼	6	3	0	6¼	0	8¼
	1	5	10	7	0	8	2	0	8	0	10¾
	1¼	7	2¾	8	8	10	1¼	0	10	1	1¼
	1½	8	7¼	10	4	12	0¾	1	0	1	4
	2	11	4½	13	7½	15	10¾	1	3¾	1	9
	2½	14	1¾	16	11¾	19	9¾	1	7¾	2	2¼
	3	16	9¼	20	1½	23	5¾	1	10½	2	6

2365. The above table we cannot suppose will require explanation; but as we wish to be quite explicit, we will merely take one example for illustrating its use, premising, that if deals are at a price between, above, or below that stated in the first column, the rules of arithmetic must be applied for the intermediate prices. Suppose deals, then, to be at 45*l.* per hundred; an inspection of the table shows that the value of 1¼-inch deal is 8*d.* per foot super., or 6*d.* run; that a 12-foot deal 2 inches thick is worth 6*s.* 8¼*d.*; and that a foot run of 3-inch deal 11 inches wide, which is the standard width, is worth 9*s.* 8¼*d.* The preceding table, which is applicable purely to joinery, is all that can be given in general terms as to the prices of work; for that which follows we are again indebted, partly to Mr. Peter Nicholson, and partly to our own industry. The information is not all that could be desired on the subject, nor, as we have before said, can constants of labour be easily obtained for every article in a building; but, as far as they go, they must be considered valuable, though they seem not to have met with the reception they deserved. The value of the labour is given as before, in parts and decimal parts of a man's labour in each description of work per diem, so that the factor to be applied to each is the rate per diem at which the journeyman is engaged. The first table subjoined is one for doors, and in the first article of it, by way of application, suppose the wages of the joiner be 5*s.* 6*d.* per diem, that = 5·5 shillings will be the factor, and the price, therefore, of the labour on a 1¼-inch door, both sides square, will be 5·5 × ·06 = ·330 shillings, or nearly 4*d.* per foot, without fitting and hanging. If to this be added the price of the quantity of deal used in it, from the foregoing table, we shall arrive at a result not far from its value. We proceed, then, in giving the constants of doors according to their most common descriptions.

Doors, 1¼ Inch thick.

2-panel, both sides square - - - - - per foot super.	·06
4-panel, both sides square - - - - -	·07
6-panel, both sides square - - - - -	·08
2-panel, quirk ovolo and bead, and square back - - -	·1
4-panel, quirk ovolo and bead, and square back - - -	·11
6-panel, quirk ovolo and bead, and square back - - -	·12
2-panel, bead and flush front, and square back - - -	·1
4-panel, bead and flush front, and square back - - -	·11
6-panel, bead and flush front, and square back - - -	·12
2-panel, bead and butt front, and square back - - -	·09
4-panel, bead and butt front, and square back - - -	·1
6-panel, bead and butt front, and square back - - -	·11
2-panel, quirk ovolo and bead on both sides - - -	·14
4-panel, quirk ovolo and bead on both sides - - -	·15
6-panel, quirk ovolo and bead on both sides - - -	·16
2-panel, bead and butt on both sides - - - -	·12
4-panel, bead and butt on both ends - - - -	·13
6-panel, bead and butt on both ends - - - -	·14
2-panel, bead and flush on both sides - - - -	·14
4-panel, bead and flush on both sides - - - -	·15
6-panel, bead and flush on both sides - - - -	·16

2366. In applying the above table to other thicknesses, for every additional thickness of one quarter of an inch the rate per foot super. must be increased ·005.

2367. When the panels are raised on one side, ·002 must be added, and double that (·004) when raised on both sides. If an astragal or ovolo is on one of the rising sides, ·003 must be added, and double that (·006) if such occur on both sides. Generally, if the number of panels be given, and the price per foot square on one side, with extra work on the other side, its price is one of the same number of panels, and the same number of panels on both sides minus the rate of the first from that of the last. But adding the difference of the second, we have the rate extra on both sides. Thus the rate is ·06 for 1¼-inch two-panel door, square on both sides, and for a two-panel door, square on one side, with quirk ovolo and bead upon the other, it is ·1. The difference is ·04, which added to ·1 = ·15 for the rate of 1¼-inch two-panel door, with ovolo and bead on both sides.

2368. We now turn to another of the items to be considered in measuring and estimating works, that of linings, wherein the difference of labour between square-framed door linings, backs, elbows, sofites, or wainscotings, and door square on both sides, where the panels and thicknesses are alike, arises only from planing the panels and the framing on the other side of the door. If the difference, therefore, per foot, on the rate of a door square on both sides, and one square on one side, with any extra work on the other side, be added to the rate of door-linings, backs, elbows, sofites, or wainscoting framed square, we shall have the rate per foot for door-linings, window-linings, or wainscoting, taking the extra work as above considered. The rails and stiles are taken in the rates as not rebated, and the framed linings for walls or apertures are supposed as made of stuff one quarter of an inch thinner than the doors. Linings are uusually about an inch thick, being stiffened by fixing to the wall; but this depends on the distance of the panel's recess from the framing, and on the depth of the moulding employed.

Framed Inch Linings.

1-panel, square as in backs	per foot super.	·051
3-panel, square as in backs, and elbows measured together		·071
4-panel, square as in backs, and elbows and sofites		·061
3-panel, moulded as in backs, and elbows together		·087
4-panel ditto and sofites measured together		·077
3-panel, quirk moulded as in backs, and elbows measured together		·095
4-panel, quirk moulded as in backs, and sofites measured together		·085

Semicircular moulded sofites in two panels seven times the straight. For each additional quarter of an inch add ·005 to the foot super.

N.B. In the above table the backs, elbows, and sofites, though numbered as of 3 and 4 panels, are only of one panel each, the number being collected.

Inch and a quarter Door-Linings, one Panel high.

Rebated	per foot super.	·051
Rebated and beaded		·058
Double rebated, not exceeding 7 inches wide		·067
Double rebated, not exceeding 7 inches wide, and one edge beaded		·071
Double rebated, not exceeding 7 inches wide, and both edges beaded		·075

If the plan be circular, the price increases as the diameter diminishes.

Semicircular heads straight on the plan are worth five times as much as straight.

Shutters, two panels in height, either shutters or flaps, inch framed, uncut. If mouldings are described, they are considered as to be laid in, but if stuck on the framing, add ·012 to the rate. Add ·016 to the rate for every extra panel, and ·012 for any extra height, and ·008 if they are quirk moulded.

Square	per foot super.	·071
Bead butt and square		·1
Bead flush and square		·111
Bead flush and bead butt		·131

Two panels in height, inch and quarter, uncut, adding for extras, as in the heading above.

Moulded and square	per foot super.	·1
Moulded bead butt		·111
Moulded bead and flush		·135
Moulded on both sides		·111
Ovolo and bead, or quirk ogee front, and square back		·103
Ovolo and bead, or quirk ogee front, with bead and butt back		·123

Wainscoting, 1¼-inch, two panels high, with square fascia, framed up to ceiling.

Square	per foot super.	·039
Moulded		·055
Quirk moulded		·063
Bead and butt		·051
Bead and flush		·059
Bead and flush, with three reeds		·075

Should either of these be framed with raised mouldings, add ·008 to the rate, or framed with more, ·006 is to be added for each additional panel in height.

Wainscoting, 1¼-inch dwarf, one panel high, including square skirting.

Square	per foot super.	·047
Moulded		·063
Quirk moulded		·071
Bead and butt		·059
Bead and flush		·067
Bead and flush, with three reeds		·083

If dwarf wainscoting be framed with two panels in height, add ·016 to the rate, as in full wainscoting. When raked to stairs, ·023 extra, and when with raised mouldings, ·007. All cappings are measured run, and the skirtings of stairs must be taken separately from their wainscoting.

Three-quarter-inch or Slit Deal, from the bench.

Edges shot	per foot super.	·004
Wrought on one side		·016
Wrought on one side, grooved, tongued, and beaded		·028
Wrought on two sides, and edges shot		·028
Wrought on two sides, grooved, tongued, and beaded		·04

When joints glued, add per foot ·004.

Inch and quarter Deal.

Wrought on one side, and edges shot	per foot super.	·02
Wrought on both sides, and edges shot		·032
Wrought on one side, and ploughed and tongued		·036
Wrought on two sides, ploughed, tongued, and beaded		·052

With glued joints, add ·004 to the rate.

Inch and half Deal.

Edges shot	per foot super.	·008
Ploughed and tongued		·024
Wrought on one side, with edges shot		·02
Wrought on both sides, with edges shot		·036
Wrought on both sides, ploughed and tongued		·052

With glued joints, add ·012 to the rate.

Two-inch Deal, from the bench.

Edges shot	per foot super.	·02
Ploughed and tongued		·036
Wrought on one side		·028
Wrought on both sides		·044
Wrought on both sides, ploughed and tongued		·056

With glued joints, add 016 to the rate.

Two-and-half-inch Deal, from the bench.

Edges shot	per foot super.	·028
Ploughed and tongued		·048
Wrought on one side		·048
Wrought on both sides		·063
Wrought on both sides, ploughed and tongued		·083

With glued joints, add ·016 to the rate.

Three-inch Deal.

Edges shot	per foot super.	·032
Ploughed and tongued		·056
Wrought on one side		·056
Wrought on both sides		·08
Wrought on both sides, ploughed and tongued		·103

With glued joints, add ·016 to the rate.

Inch Boarding, one side planed.

Ploughed and tongued	per foot super.	·24
Glued joint		·03
Clamped		·056
Mortice clamped		·063
Laid with straight joint in floors		·02
Keyed dado		·044
Keyed in backs and elbows		·056
Wrought on both sides, ploughed and tongued		·036
Wrought on both sides, glued joint		·04
Groove-clamped flaps to shutters, in one height		·053
Clamped flaps to shutters, in two heights		·071
Inch mortice, clamped, outside shutters		·063
Ledged doors, with plain joint		·044
Ledged doors, ploughed, tongued, and beaded		·056

Preparing Flooring Boards, guaged to a width, and rebated to a thickness not more than 9 inches wide.

Inch deals, 10 feet long	for each board	·063
Inch deals, 12 feet long		·075

Preparing Flooring Boards.

Inch deals, 14 feet long	for each board	·087
Inch and quarter deals, 10 feet long		·071
Inch and quarter deals, 12 feet long		·083
Inch and quarter deals, 14 feet long		·1
Inch and quarter battens, 10 feet long		·044
Inch and quarter battens, 12 feet long		·056
Inch and quarter battens, 14 feet long		·075

Mouldings, from the bench.

Double-faced architraves	per foot super.	·111
Base and surbase		·127
When above 4 inches girt, struck by hand		·127

In a combination of mouldings, with more than two quirks, add ·016 for each.

Inch and Inch and quarter framed Grounds to Doors, from the bench.

Both edges square	per foot run	·028
One edge square, and the other rebated and beaded		·032
Rebated on one edge, and beaded on both edges		.036

Framed to a circular plan with flat sweeps, the head to be thrice the rate of straight, but the smaller the sweep the greater the rate.

Running Articles.

Beads and fillets	per foot run	·004
Bead or ogee capping		·016
Inch ogee		·016
Inch quirked ogee, or ovolo and bead		·023
Square angle staff, rebated		·028
Angle staff, rebated and beaded		·048
Single cornice or architrave		·048
Small reeds in reeded mouldings, stuck by hand to ½ an inch		·004
Reeds above ½ an inch, stuck by hand, including grooved space		·008
Grooves in ornamental work		·004
Narrow ground to skirting		·011
Narrow ground to skirting, rebated or grooved		·016
Narrow ground, framed to chimneys		·032
Double-beaded chair rail		·023

Plugging is included in the above rates. Such of the articles as are circular on plan, to be double rate.

Legs, rails, and runners to dressers	per foot run	·055
Rule joints to shutters		·063

Stairs, inch and quarter nailed steps, with carriages.

Flyers	per foot super. fixed	·08
Winders		·111
Flyers, moulded and glued, with close string board		·103
Winders, moulded and glued, with close string board		·135
Moulded planceer under steps		·04
Housings to flyers	each	·127
Housings to winders		·2
Common cut brackets to flyers		·143
Common cut brackets to winders		·286

Fancy brackets to be paid for extra, according to their value

Handrail, 2 inches deep and 2½ inches broad.

Deal, moulded	per foot run fixed	·111
Deal, moulded and ramped		·495
Deal, moulded, level, circular		·413
Deal, moulded, wreathed		1·2
Mahogany, moulded, straight		·263
Mahogany, moulded, ramped		·831
Mahogany, moulded, ramped, swan-necked		·927
Mahogany, moulded, level, circular		1·08
Mahogany, moulded, wreathed, from 12 in. and above		1·6
Mahogany, moulded, wreathed, under 12 in.		1·8
Mahogany, moulded, wreathed, not less than 12 in. opening		2·3
Mahogany, moulded, wreathed, under 12 in. opening		3·4

Handrail.

Extra sinking to rail, for iron balusters	per foot run fixed	·032
Extra sinking to rail, in ramp or wreath		·1
Mahogany moulded cap, wrought by hand, each		·495
Mahogany moulded cap, turned and mitred, each		·4
Mahogany scroll, each		1·8
Making and fixing each joint with joint screw		·231
Making model and fixing iron balusters		2·095
Making model and fixing iron columns to curtail, each		2·142
Preparing and fixing deal bar balusters, each		·04
Preparing and fixing deal bar balusters, dovetailed to steps		·056

Every half rail is measured two-thirds of a whole one; and all rails are measured 3 inches beyond the springing of every wreath or circular part.

All cylinders used in rails, glued up in thicknesses, to be paid for extra.

The following have not been before computed: —

French Casement Frames.

Plain solid frames, oak sunk sills, weathered and throated for 1½ inch French casements, quarters not exceeding 4 by 3	per foot super. fixed	·043
Ditto, for 2-inch French casements, quarters 4 by 4		·057
Deal-cased frames, oak sunk sills, with wainscot stiles and beads, for 2-inch French casements		·086
Circular head, measured square		·258
Circular circular head, curve ¼ inch to a foot		·727
If with mahogany stiles and beads, add on the wainscot		·021
If any of the above are for 2½-inch sashes or casements, add on the deal		·014
If any on the wainscot		·021
If any on the mahogany		·028
Extra grooves or beads, add	per foot run	·014

Circular on plan, flat sweep, once and a half the straight.

Quirk on plan, double.

Sashes and Frames, fitted and hung.

Deal cased frames, oak sunk sills, 1½-inch ovolo sashes, single hung brass pulleys, best white lines, and iron weights	per foot super.	·086
Ditto, double hung		·100
Ditto, double hung, circular head, measured square		·257
Ditto, circular on plan, flat sweep		·143
Deal cased frames, oak sunk sills, 2-inch ovolo sashes, single hung, brass pulleys, best white lines, and iron weights		·100
Ditto, double hung		·107
Ditto, double hung, circular head, measured square		·272
Ditto, double hung, circular on plan, flat sweep		·157
Circular circular head, ¼ inch to the foot		·770
Deal cased frames, oak sunk sills, wainscot pulley pieces and beads, 1½-inch wainscot astragal sashes, brass axle pulleys, single hung with patent lines		·121
Ditto, double hung		·143
Deal cased frames, oak sunk sills, wainscoat pulley pieces and beads, 1½-inch wainscot astragal sashes, brass axle pulleys with patent lines, circular on plan, flat sweep		·172
Circular circular head, ¼ inch to the foot		·866
Deal cased frames, oak sunk sills, wainscot pulley pieces and beads, 2-inch wainscot astragal sashes, brass axle pulleys, double hung with patent lines		·143
Ditto, circular head, measured square		·342
Ditto, circular on plan, flat sweep		·214
Circular circular head, ¼ inch to the foot		·909
Deal cased frames, oak sunk sills, mahogany pulley pieces and beads, 1½-inch Spanish mahogany astragal sashes, brass pulleys and patent lines, single hung		·157
Ditto, double hung		·171
Ditto, circular head, measured square		·371
Ditto, circular on plan, flat sweep		·257
Circular circular head, ¼ inch to the foot		·98

Deal cased frames, oak sunk sills, mahogany pulley pieces and

SASHES AND FRAMES.

beads, 2-inch Spanish mahogany astragal sashes, brass pulleys and patent lines	per foot super.	·178
Ditto, circular head, measured square		·399
Ditto, circular on plan, flat sweep		·272
Deal cased frames, oak sunk sills, mahogany pulley pieces and beads, 2½-inch Spanish mahogany astragal sashes, brass axle pulleys and patent lines		·243
Ditto, circular on plan, flat sweep		·315
Circular circular head ¼ inch to the foot		1·123
If Honduras mahogany, deduct from the straight		·029
If Honduras mahogany, deduct from the circular		·043
If lamb's tongue, or other modern modelled bar, add on the astragal		·014

VENETIAN AND PALLADIAN SASHES AND FRAMES, fitted and hung.

Venetian deal cased frames, oak sunk sills, 1½ inch ovolo sashes, brass pulleys, double hung with best flax line and iron weights,	per foot super.	·111
Ditto, with 2-inch sashes		·129
Ditto, circular on plan, flat sweep		·172
Palladian head, measured square		·286
Circular Palladian head, measured square		·866
Venetian deal cased frames, wainscot pulley pieces and beads, 1½-inch wainscot astragal sashes, brass pulleys and patent lines, double hung		·157
Ditto, with 2-inch sashes		·172
•Ditto, circular on plan, flat sweep		·200
Ditto, Palladian head, measured square		·342
Circular Palladian head, measured square		·952
If any of the above are in 2½-inch wainscot, add on the 2-inch straight		·014
Ditto, on the circular		·028
Ditto, on the circular circular		·043
If in Spanish mahogany, add on similar article in straight wainscot		·043
Ditto, on the circular		·114
If lamb's tongue, add on the astragal		·007
When any of the above sashes are with a bevelled bar up to the rebate, add on the astragal		·014

FRENCH CASEMENTS, fitted and hung.

1½-inch deal ovolo	per foot super.	·057
2-inch deal ovolo		·064
2½-inch deal ovolo		·071
1½-inch wainscot		·078
2-inch wainscot		·086
2½-inch wainscot		·100
1½-inch Honduras mahogany		·086
2-inch Honduras mahogany		·100
2½-inch Honduras mahogany		·114
1½-inch Spanish mahogany		·100
2-inch Spanish mahogany		·114
2½-inch Spanish mahogany		·129
If with margin lights, add on the deal		·018
If with margin lights, add on the wainscot		·029
If with margin lights, add on the mahogany		·036
If in two heights, add		·021
If in two heights add, on the wainscot		·029
If in two heights, add on the mahogany		·043
Circular on the plan, flat sweep, once and a half the straight, and exceeding ¼ inch to the foot, double.		
If astragal and hollow lamb's tongue, or other modern bar, add		·014
If with bevelled bars up to the rebate, add on the astragal and hollow		·007
Extra rebated edges, grooves, or beads, in deal	per foot run	·014
Extra rebated edges, grooves, or beads, in wainscot		·021
Extra rebated edges, grooves, or beads, in mahogany		·028

SKYLIGHTS, fixed.

1½-inch deal ovolo	per foot super.	·043

Skylights.

2-inch deal ovolo	per foot super.	·050
2-inch oak ovolo		·071
If astragal and ovolo, add		·007

Dado.

¾-inch deal, keyed	per foot super.	·043
1-inch deal keyed		·050
Raking and scribed to steps, add		·012
If ploughed and tongued, add		·007
If feather-tongued, add		·012
Circular on plan, flat sweep		·143
Circular on plan, quirk sweep		·229
If 1¼-inch deal, add on the straight		·007
If 1¼-inch deal, add on the circular		·014
Narrow dado grounds		·018
Narrow dado grounds, circular flat sweep		·043

2369. We have now enumerated the principal articles of joinery in use. If further information be sought, and the reader have not the means of tracing the value in the way by which the constants already given have been obtained, he may refer to some of the price books, whereof we consider Skyring's to be as well digested as any of those that are annually published.

2370. Slater. The work of the slater is measured and estimated by the square of 100 feet superficial. Of the different sorts of slate, and how much a given quantity of each will cover, we have already spoken in Chap. II. Sect. IX. (1798, *et seq.*) To measure slating, in addition to the nett measure of the work, 6 inches are allowed for all the eaves, and 4 inches by their length for hips; such allowance being made in the first-named case because the slates are there double, and in the latter case for the waste in cutting away the sides of the slates to fit. When rags or imperial slates are used an additional allowance of 9 inches is made for the eaves, because those slates run larger than the other sorts.

2371. Mason. Solid works, such as pilasters, cornices, coping, stringings, and other solid works, should be first measured to ascertain the cubic quantity of stone they contain as going from the *banker* to the building; and on this, work, as it may happen to be the plain work, sunk work, moulded or circular work, must be measured in superficial feet and separately valued. It is usual to allow a plain face to each joint, but no more than one should be taken to a 3-feet length. In staircases the flyers should be taken where splayed on the back, their full length and width by three fifths of the depth of the riser, to allow for waste in getting two of the steps from the same block of stone. The measurement for the winders seems to be most properly conducted by ascertaining the nett cubic contents of them, and then making the allowance for waste. Indeed this is a more proper and satisfactory mode for the flyers. The top of the treads are then taken on the superficies as plain work, and the fronts and ends of the risers as moulded work. In an open staircase, the under side of the flyers is measured as plain work; the under side of the winders as circular plain work; the rebates, cuttings out, pinnings in, &c., as they are found. Cylindrical work, such as of columns, after the cube quantity is ascertained, is measured as equal to plain work twice taken. In Portland dressings to chimneys, wherever edges appear, it is customary to add an inch to the dimensions for extra labour; to marble, ¾ of an inch; or to take the running dimensions of the edges.

2372. Paving slabs and stones under 2 inches thick are taken by superficial measure. Cornices are measured by obtaining their girt, and multiplying by their length for the quantity of moulded work in them.

2373. The following are a few constants of the chief articles of labour in mason's work, applicable, as before mentioned, in the carpenter's and joiner's works.

Plain work	per foot super.	·166
Plain work, rubbed to face		·18
Plain work, tooled		·208
Sunk work		·222
Moulded work		·278
Moulded work, stopped		·333
Gothic moulded work		·445
Gothic moulded work, stopped		·528
Gothic moulded work, circular		·556
Circular plain work		·264
Circular sunk plain work		·333
Circular moulded plain work		·361
Circular, plain moulded work, stopped		·416

2374. Founder. The proper mode of estimating cast iron is by the ton or cwt. Moulds for the castings, when out of the common course, are charged extra. Very often, too, cast iron pipes and gutters are, according to their sizes, charged by the yard. (See 1754, *et seq.*)

2375. Smith and Ironmonger. Wrought iron for chimney bars, iron ties, screw bolts, balusters with straps, area gratings, handrails and balusters, hook-and-eye hinges, brackets for shelves, chains for posts, wrought iron columns with caps and bases, fancy iron railing, casements, shutterbars, and the like, are charged by the pound, at various prices, according to the nature of the work. In the ironmonger's department nails and brads are charged by the hundred, though sold by weight, seldom exceeding 900 to the 1000. Screws, which take their names from their length, are charged by the dozen. Cast, and also wrought butts and screws, cast and wrought back flaps, butts and screws, side or H hinges, with screws, by the pair. All sorts of bolts with screws, of which the round part of the bolt determines the length, by the inch. H hinges and cross garnet hinges, by the pair. Other hinges and screws by the piece. Locks by the piece. Pulleys according to their diameters. On all ironmongery 20 per cent. is charged on the prime cost. (See 2253, *et seq.*)

2376. Plasterer. The work of the plasterer is measured, generally, by the yard. The most usual way of measuring stucco partitions and walls is, to take the height from the upper edge of the ground to half way up the cornice, the extra price of the stucco making good for the deficiency of floated work under it. In ceilings and other work, the surface under the cornice is often taken, because there is no deficiency but in the setting, and that is compensated for by the labour in making good. Cornices are measured by the foot, and estimated according to the quantity of mouldings and enrichments they contain. Where there are more than four angles in a room, each extra one is charged at the price per foot run extra of the cornice. Stucco reveals are charged per foot run, and according to their width of 4 or 9 inches or more. Quirks, arrisses, and beads by the foot run, as are margins to raised panels, small plain mouldings, &c. In the case of enriched cornices and mouldings, and flowers to ceilings, they must be considered with reference to the size and quantity of ornament. For these, the papier maché ornaments, (see 2251.) which are much lighter, are coming now into very general use, and from the ease and security with which they are fixed, will, we have no doubt, within no very distant period, supersede all use of plaster ornaments. In subsection 2248 will be found some information useful in the investigation of the value of plasterers' work, and which might form the basis for a set of constants under that head. But we have not been able to obtain sufficient data for carrying them completely out; which, from the minor importance of this branch of building, is perhaps of no very great consequence.

2377. Plumber. The work of this artificer is charged by the cwt., to which is added the labour of laying the lead. Water pipes, rain-water pipes, and funnel pipes are charged by the foot, according to their diameter; so also are socket pipes for sinks, joints being separately paid for. Common lead pumps, with iron work, including bucket, sucker, &c., at so much each; the same with hydraulic and other pumps, according to their diameters. In the same manner are charged water-closets, basins, air traps, washers and plugs, spindle valves, stop-cocks, ball-cocks, &c. (See 2212, *et seq.*)

2378. Glazier. The work of the glazier is measured and estimated by the superficial foot, according to the quality of the glass used; it is always measured between the rebates. (See 2225, *et seq.*)

2379. Painter. In the measurement and estimation of painting, the superficial quantity is taken, allowing all edges, sinkings, and girths as they appear. When work is cut in on both edges it is taken by the foot run. The quantity of feet is reduced to yards, by which painting is charged for large quantities. In taking iron railing the two sides are measured as flat work; but if it be full of ornament, once and a half, or twice, is taken for each side. Sash frames are taken each, and sash squares by the dozen. On gilding we have already spoken in Sect. XII. (2267, *et seq.*) Cornices, reveals to windows and doors, strings, window sills, water trunks and gutters, handrails, newels, &c., are taken by the foot run. Many small articles by the piece. Plain and enriched cornices by the foot run, according to the quantity of work in them. Work done from a ladder is paid for extra. The price depends on the number of times over that the work is painted; and the labour is usually considered as one third of the price charged. Imitations of woods and marbles are also charged extra.

2380. Paperhanger. In common papers the price varies according to the colours or quantity of blocks used in printing it. Embossed and other papers are of higher prices. These, as well as lining paper, are charged by the piece, containing 63 feet super. The hanging is charged separate, and borders, mouldings, &c. by the yard run. (See 2278.)

CHAP. IV.

MEDIUM OF EXPRESSION.

Sect. I.

DRAWING IN GENERAL.

2381. Under this section it is not our intention to enter into the refinements of the art, but merely to make the attempt of directing the student to the first principles of a faithful representation of ordinary and familiar objects, with all their imperfections; or, in other words, of transferring to a plane surface what the artist actually sees or conceives in his mind. This power is of vital importance to the architect, and without it he is unworthy the name. The practice, in these days, of employing draughtsmen to make drawings for competitions, is not less disgraceful to those who have recourse to such a practice, than to the committees and other bodies, who are, in nine cases out of ten, grievously misled and deceived by the practice. Every work in a competition should be strictly limited to lines in its representation, and without colour or shadow. It is not very long since that, in a great competition, we saw drawings shadowed in a way that must have had some other luminary than the sun to light them, unless he had changed for the moment the usual course in which he travels through the heavens, for the gratification of the luminous draughtsman who craved his special aid. We regret that architects generally do not throw aside the pernicious system. There are some few who have done so, and are indebted to the practice for the rank they hold. We shall here merely add, before entering on the subject, that in our opinion, the greatest curse that in these days has fallen on architecture, is the employment of draughtsmen, who with their trumpery colouring and violent effects mislead the silly men and common-place critics that usually decide upon the merits of their works. In the days of Jones, Wren, and Vanbrugh, this was fortunately not the case. We ourselves possess more than one drawing of Wren, which fully prove that the medium of expression for the workman in our own art was then simple, and wanted not such silly aids as those whereof we have been speaking. If proof be required, let the authorities, who ought better to direct these matters, make a pilgrimage to Oxford, and there examine the drawings of Wren, whose equal we cannot point to in the present age. Let them examine the way in which Inigo Jones went to work from the MS. notes on his copy of Palladio, now at Worcester College, and we may hope to see better days. The present mode is that of making a pretty picture; and he who makes the prettiest, provided he have a reasonable number of friends in a committee, is the lucky candidate. But we are wandering from the subject, and must return to that which heads the section.

2382. The usual mode of teaching drawing now in use is, as we conceive, among the most absurd and extravagant methods of imparting instruction that can be well conceived. The learner is usually first put to copying drawings or prints, on which he is occupied for a considerable time. How much more would he learn, and how much more quickly, by drawing at once from the figure or its parts; thus at once, for that the thing is quite possible, we know from experience, acquiring the power of transferring to a plane surface the representation of that which is placed before his eye? And here we deem it proper to apprise the reader that the representation of *form* is all that the architect requires. The power of doing this is no slight acquirement. Under perspective, we shall see in the following section, that for all geometrical solids the representation is dependent on mechanical means, of which every one may easily possess himself; and these may, if it be desirable, be shadowed truly by the methods given in Section III.; but the undulating form of the figure, and the infinite variety of a landscape, by changing the situation of the spectator, is more the matter now to be considered. As to the materials to be used for the purpose, a black lead pencil and some Indian ink or sepia are all that the architect can want. On them we shall not therefore stop to waste his and our own time. It is the practice of going further that has excited the observations with which we began.

2383. We are fully aware of the impossibility by writing merely, without the aid of a master at the student's back, to teach any one the art of drawing. Much, nevertheless, may be imparted, namely, the mechanical means, assisted by a general knowledge of perspective, to place the different parts of a figure or landscape not so violently out of their proper places in the representation as to offend the eye. Here let us mention that our impression is, and we do not believe that any artist will venture to contradict it, that he who can draw the figure will be able to draw any other object or objects that are submitted to him for representation. Besides this, the freedom he will obtain in the use of his pencil by first employing it in this way, will impart a facility which is by no other means to be attained. This was one of the great powers possessed by the artists of Italy; this made them painters, sculptors, and architects, combining the three arts in one person, and this, lost, has separated the three arts, and the want of it reduced our Academy, with a few exceptions, to parties of whom, with all our best feelings towards them, it cannot be said they are those upon whom the mantle has fallen to do the like. Portrait painting, good enough of itself, has banished real art. This, however, is not the fault of the Academy, but of the selfish feeling of the nation.

2384. We have also, before entering on the few principles to be given, to premise that though for the painter and sculptor a knowledge of anatomy is absolutely requisite, we do not insist upon that for our purpose. It is only to be so far known as to remember that the carpentry of man is his skeleton, and the muscles and integuments the lath and plaster put on the framing. We mean, in fact, that a general knowledge of it for drawing is well to be possessed.

2385. The method proposed in the following pages is as old, at least in principle, as the time at which we ourselves began to learn the art; and we are therefore surprised that it should have been lately published as new in Paris, by M. Dupuis. ("*De l'Enseignement du Dessin sous le point de vue industriel,*" 1836.) The principles of the work, however, are perhaps better expressed and arranged, in some respects, than we might have presented them to the reader: and we shall not, therefore, apologise to our readers for the free use we intend to make of it, premising, however, that we do not in any way admit its novelty, and that, in respect to the whole figure and the application of the method to landscapes, what follows is not found in the work of M. Dupuis.

2386. Outline is the foundation of all drawing, the elementary alphabet of graphic art. Every representation of an object, or series of objects, however complicated, is, in reality, but a set of outlines modified by right and curved lines. The knowledge of these lines, and of their several properties, will greatly abridge the labour of the student, inasmuch as the power, if we may so express ourselves, of reading and writing them by calculating the relations of size and distance which exist between their parts, is, in fact, the faculty of drawing. The elements of perspective may be previously so far entered upon as to acquire facility in drawing in every position, without the aid of those rules which are given in Sect. II.; the cube, cylinder, sphere, pyramid, and other solid bodies, upon which, from the objects themselves actually before him, the student may begin to work. Having acquired freedom and power of accurate representation in this respect, and also a dexterity in the use of his pencil generally, he may commence his operations on the figure itself.

2387. Between the ancient mode of teaching the student (we will take the head, for instance, shown in *fig.* 809. as the first roughing of the leading lines of that which in *fig.* 812. has reached its completion) and the method practised by M. Dupuis, the only difference is this, that M. D., instead of letting the student form the rough outline at once from the finished bust, roughing out on paper the principal masses, provides a series of models roughly bossed out in their different stages, which he makes the student draw. The system is ingenious; but as the greatest artists have been made without the modification in question, we do not think it material; at all events, the principles are the same. M. Dupuis, for this purpose, has a series of sixteen models, the first of each four of the series are quite sufficient to show the old as well as his own practice. Thus, in *fig.* 809., the general mass of the oval of the head is given, in which it is seen that the profile is indicated by an obtuse angle, whose extreme point corresponds with the lower part of the nose, and the lines at one extremity terminate with the roots or commencement of the hair, and at the other with the lower jaw. The form of the rest of the head is the result of combining the most projecting points of it by curved lines, in short, of supposing a rough mass, out of which the sculptor might actually, in marble or other material, form the head.

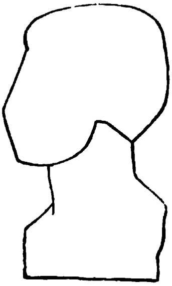
Fig. 809.

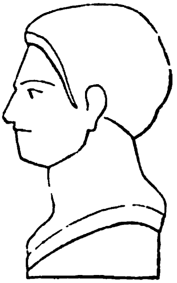
Fig. 810.

2388. The next step is exhibited in *fig.* 810., with the four principal divisions: the occipital to the beginning of the hair, the forehead to the line of the eyes, the projection of the nose, and the inferior part of the face, with some indication of the mouth.

2389. In *fig.* 811. it will be seen that another step is gained. The eyes (here only one appears, but we speak with reference to the subject, being less in profile), the mouth, the chin, and the ear are more clearly marked out, with some sort of expression of the whole work, but still without details, though sufficiently indicating that little more is necessary to bring the rude sketch of *fig.* 809. to a resemblance.

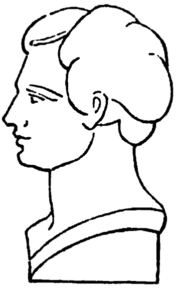

Fig. 811.

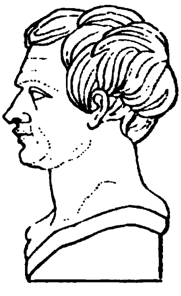

Fig. 812.

2390. In *fig.* 812. this is obtained; but still, according to the degree to which an artist considers finishing necessary, to be further pursued and carried through to make a perfect drawing; all that is here intended being to show the principles upon which the matter is conducted, and upon which we shall presently have further observations to make. It will be observed that on the shadowing and finishing in this way, the drawings the student may make we set no value: when he can draw, if those matters be of importance to him, they will not be difficult of acquisition. We scarcely think it here necessary to repeat that, having accomplished the art of drawing with tolerable correctness the figure, the architect will have few difficulties to contend with in drawing the most complex and elaborate ornaments employed in architecture. The principles are precisely the same; but we wish here to impress upon him the necessity of recurring to nature herself for his ornaments: a practice which will always impart a freshness and novelty to them which even imitation of the antique will not impart.

2391. The port crayon, whether carrying chalk or a black lead pencil of moderate weight and size, say full seven inches long, is the best instrument to put into the hands of the beginner. The first object he must consider in roughing the subject, as in *fig.* 809., is the relation the height of the whole bears to its width; and this determined, he must proceed to get the general contour, without regard to any internal divisions, and thus proceed by subdivisions, bearing the relative proportions to each other of the model, comparing them with one another and with the whole. We will now show how the port crayon assists in this operation. Let the pupil be supposed seated before the model, at such a distance from it that at a single look, without changing the position of his head upwards, downwards, or sideways, his eye takes in the whole of it. The strictest attention to this point is necessary, for difficulties immediately present themselves if he is too near, as well as if he is too far from it. And here let it be observed that the visual rays (see *fig.* 813.) upon every object may be compared to the legs of a pair of compasses, which open wider as we approach the object and close as we recede from it. This is a law of perspective well known, and which the student may easily prove by experiment, keeping the head of the compasses near his eye, and opening the legs to take in, in looking along them, any dimension of an object. He will soon find that as he approaches such object he must open the legs wider in order to comprise within them the given dimension. Hence every diameter or dimension, separately considered, is comprised in the divergence of the visual rays. It is on this account that, being at a proper distance, any moveable measure which with a free motion of his body he can interpose upon some one of the points of the distance between his eye and the model, may, though much less than the model itself, take in the whole field of view, reach the extremities of the dimension, and consequently become of great assistance in certain mathematical measures. For by applying such a measure to one division only of the model, we shall obtain, as it were, an integer for finding a great many others into which the model may be subdivided.

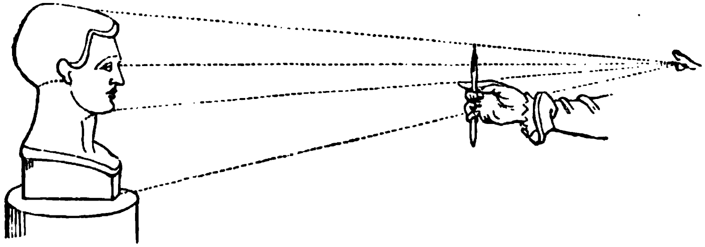

Fig. 813.

2392. Thus, taking *fig.* 809., which is profile, and supposing the width at the neck unity, if this is twice and a half contained in the general height of the bust, we have immediately the proportions of one to two and a half, which may be immediately set out on the paper or canvas. This is not all; the integer or unity obtained by the diameter of the neck serves also for measuring the horizontal diameter of the head, and also of the bust; whence new proportions may be obtained. So much for the first casting of the general form. Now, in the entire bust, as respects the head only, suppose we wish to obtain the proportions of the principal divisions, — for example, from the base of the bust to the base of the chin, — we may establish another integer to measure other parts; as, if from the point of view, the distance from the base of the bust to the base of the chin is the same as from the last to the summit of the head, the learner would have nothing more to do in that respect than to divide the whole height into two equal parts. On the same principle, passing from divisions to subdivisions, the distance between the base of the chin and the point whence the nose begins to project, may be found a measure for the height of the nose, and from thence to the top of the cranium. We are here merely showing the method of obtaining different integers for measuring the different parts mentioned; others will in practice occur continually, after a very little practice. We do not suppose our readers will believe that we propose to teach drawing by mathematical rules; we now only speak of obtaining points from which undulating and varying lines are to spring and return, and which none but a fine and sensitive eye will be able to express. But to return to the port crayon, which is the moveable measure or compasses whereto we have alluded, and requires only skilful handling to perform the offices of compasses, square, plumb rule, and level. By interposing it (see *fig.* 813.) on the divergence of the visual rays between the eye and the object, we may estimate the relative proportions; since in the field of view the learner may apply it to the whole or any of the parts, and make any one a measure for another. For this purpose he must hold it, as shown in the figure, steadily and at arm's length. Any portion of it that is cut by the visual rays between any two parts of the object, becomes the integer for the measurement of other parts whereof we have been speaking. This in the drawing will be increased according as the size is greater or less than the portion of the port crayon intercepting the visual rays. This process may be easily accomplished by making, upon one and the same line of the visual ray, the extreme point of the port crayon to touch one of the extremities of the proportion sought upon the model, so that they may exactly correspond. Then at the same time fixing the thumb or fore-finger where the visual ray from the other extremity is intercepted, we shall find any equal length by moving the port crayon with the thumb and fore-finger fixed to any other part we want, as to size, to compare with the first, or by using the same expedient to other parts, other integers may be found. The different integers, indeed, which may be thus obtained is infinite. The port crayon will also serve the purpose of a plumb bob by laying hold of it by the chalk, and holding it just only so tight between the fingers as to prevent its falling, so that its own gravity makes it assume a vertical direction. Doing so, if it then be held up to intercept the visual rays, we may discover the proportion in which a line swells whose directon approaches the vertical, as also the quantity one part projects before another in the model; and comparing this again with the integer, obtain new points for starting from. Again, by holding it before the eye in an horizontal direction, we shall obtain the different parts of the model that lie before the eye in the same horizontal line. By degrees we shall thus soon find the eye become familiarised with the model it contemplates; judgment in arranging the parts supervenes; the hand becomes bold and unhesitating, and the leading forms are quickly transferred to the paper or canvas to be subdivided to such extent as is required by the degree of finish intended to be bestowed upon the drawing.

2393. The process that we have considered more with relation to the bust is equally applicable to the whole figure. In *fig.* 814. we have more particularly shown by the dotted lines the horizontal and vertical use of the port crayon; but the previous adjustment of some measure of unity for proportioning the great divisions to each other is also applied to it as already stated. In the figure, EE is the line of the horizon, or that level with the eye; it will be

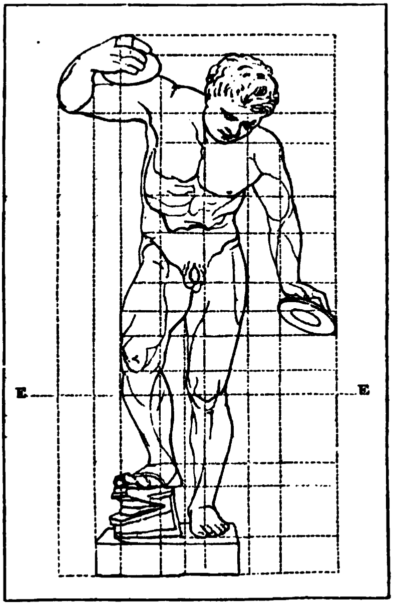

Fig. 814.

seen passing through the knee of that leg upon which the principal weight of the body is thrown.

2394. Though our object in this section is to give only a notion of the way of transferring to paper or canvas such objects as present themselves, we think it proper to hint at a few general matters which the student will do well to consider, and these relate to the balance and motion of the human figure. Geometry and arithmetic were with the painters of antiquity of such importance that Pamphilus the master of Apelles declared, without them art could not be perfected. Vitruvius particularly tells us the same thing, and, as follows, gives the proportions of the human figure: — "From the chin to the top of the forehead, or to the roots of the hair, is a tenth part of the height of the whole body; from the chin to the crown of the head is an eighth part of the whole height; and from the nape of the neck to the crown of the head, the same. From the upper part of the breast to the roots of the hair, a sixth; to the crown of the head, a fourth. A third part of the height of the face is equal to that from the chin to the under side of the nostrils, and thence to the middle of the eyebrows the same: from the last to the roots of the hair, where the forehead ends, the remaining third part. The length of the foot is a sixth part of the height of the body; the fore-arm, a fourth part; the width of the breast a fourth part. Similarly," continues our author, "have the other members their due proportions, by attention to which the ancient painters and sculptors obtained so much reputation. Just so, the parts of temples should correspond with each other and with the whole. The navel is naturally placed in the centre of the human body; and if a man lie with his face upwards, and his hands and feet extended, and from his navel as the centre, a circle be described, it will touch his fingers and toes. It is not alone by a circle that the human body is thus circumscribed, as may be seen (*fig.* 815.) by placing it within a square. For, measuring from the feet to the crown of the head, and then across the arms fully extended, we find the latter measure equal to the former; so that the lines at right angles to each other, enclosing the figure, will form a square."

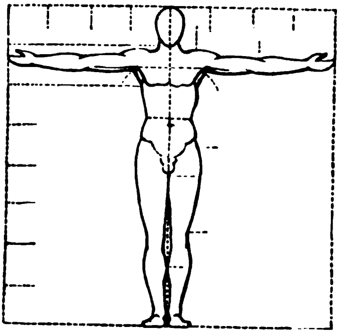
Fig. 815.

2395. "How well," says Flaxman (*Lectures on Sculpture*), "the ancients understood the balance of the figure, is proved by the two books of Archimedes on that subject; besides, it is impossible to see the numerous figures, springing, jumping, dancing, and falling, in the Herculaneum paintings, on the painted vases, and the antique basso-rilievos, without being assured that the painters and sculptors must have employed geometrical figures to determine the degrees of curvature in the body, and angular or rectilinear extent of the limbs, and to fix the centre of gravity." Leonardo da Vinci has illustrated the subject in his *Trattato di Pittura*, a perusal of which cannot fail of being highly beneficial to the student.

2396. As in all other bodies, the centre of gravity of the human figure is that point from which, if suspended, the figure would remain at rest when turned round upon it. Flaxman, by some strange mistake, has described the centre of gravity as "an imaginary straight *line*, which falls from the gullet between the ankles to the ground, when it (the figure) is perfectly upright, equally poised on both feet, with the hands hanging down on each side." (*Fig.* 816.). The fact is, that the centre of gravity is found to be in a line so drawn, or rather removed backwards from it, in a vertical plane returning from that line.

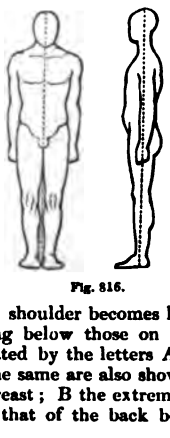
Fig. 816.

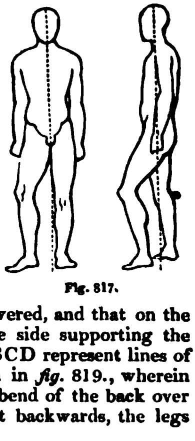
Fig. 817.

2397. Motion implies change of position; for instance, in *fig.* 817., the weight of the figure is thrown on one leg, hence a line passing through the centre of gravity falls from the gullet on one leg, on which side also the shoulder becomes lowered, and that on the opposite side raised; the hip and knee sinking below those on the side supporting the weight. In *fig.* 818. the dotted lines terminated by the letters ABCD represent lines of motion, as also the extent of such motion. The same are also shown in *fig.* 819., wherein A shows the inclination of the head to the breast; B the extreme bend of the back over the legs, without changing their position; C that of the back bent backwards, the legs remaining in the same position. If the back be bent as far as D, the thighs and legs will project as far as E.

2398. Referring back to *fig.* 817. for comparison, as the commencement of motion, with *fig.* 820., we shall immediately see that the preparation for running consists in throwing the balance beyond the standing foot; and that when the centre of gravity, which is now about to take place, falls out of the common base, the hinder leg must be out, and off the ground, to balance the fore part of the figure, which would otherwise fall.

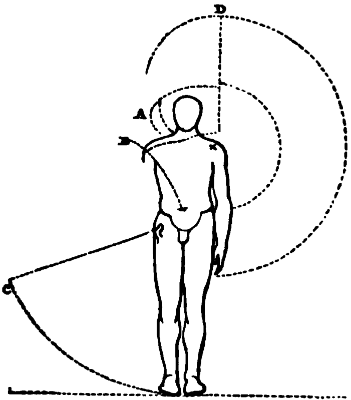

Fig. 818.

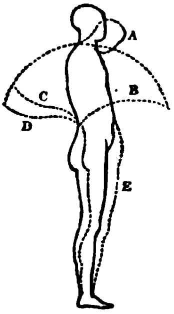

Fig. 819.

2399. In preparing to strike (*fig.* 821.), the figure is thrown back at the beginning of the action to give force to the blow: the dotted line shows the extent of the springing forward, in which the action is ended by the fall of the blow upon the object.

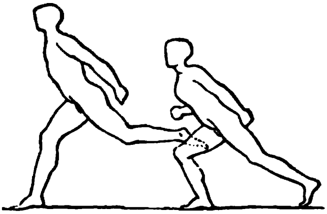

Fig. 820.

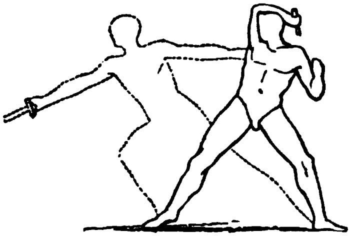

Fig. 821.

2400. In *fig.* 822., bearing a weight, the combined centres of gravity of the figure and the weight to be borne must be found; and through it the line falls between the feet, if the whole weight rests equally on both, or on the supporting foot, if the weight is thrown upon one. Flaxman, who was a finer artist than a geometrician, has, in his lectures, fallen into another mistake on this head, by saying the centre of gravity is the centre of the incumbent weight, which is absurd; because the figure has not only to balance the weight itself, but also its own weight.

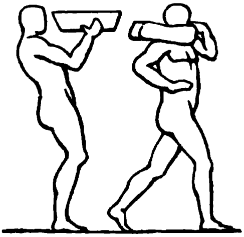

Fig. 822.

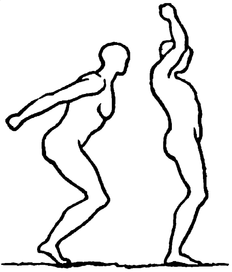

Fig. 823.

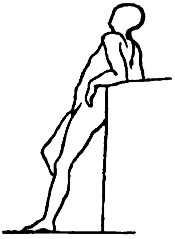

Fig. 824.

2401. In leaping (*fig.* 823.), the body and thighs are drawn together to prepare for the spring; the muscles of the leg draw up the heel, and the figure rests on the ball of the foot; the arms are thrown back to be ready immediately for swinging forward, and thus assisting in the impulse. When the figure alights, the arms, at the instant of alighting, will be found raised above the head; and a line dropped from the centre of gravity will be found to fall near the heels.

2402. In leaning (*fig.* 824.), if on more than one point, the greatest weight is about that point on which the figure chiefly rests.

2403. *Fig.* 825. is a flying, and *fig.*826. a falling figure, both whereof being in motion through the air rest on no point. In the first it will be observed that the heaviest portion of the figure is bounded by lines inclined upwards; as in falling the heaviest portion of it has a downward direction We have thought these elements would be useful, as exhibiting those leading principles without the comprehension whereof no motion or action can be well expressed. "Every change," says Flaxman, "of position or action in the human figure will present the diligent student with some new application of principles, and some valuable example for his imitation."

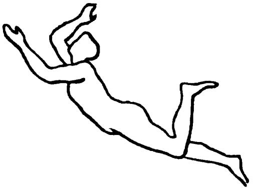

Fig. 825.

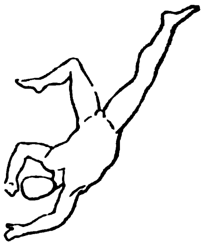

Fig. 826.

2404. We shall close this section with the application of the principles detailed in the management of the port crayon to the drawing of landscapes. The subject of *figs.* 827.

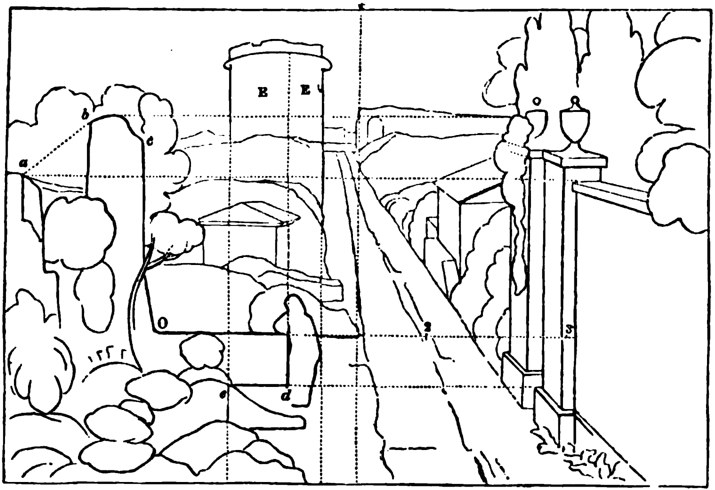

Fig. 827.

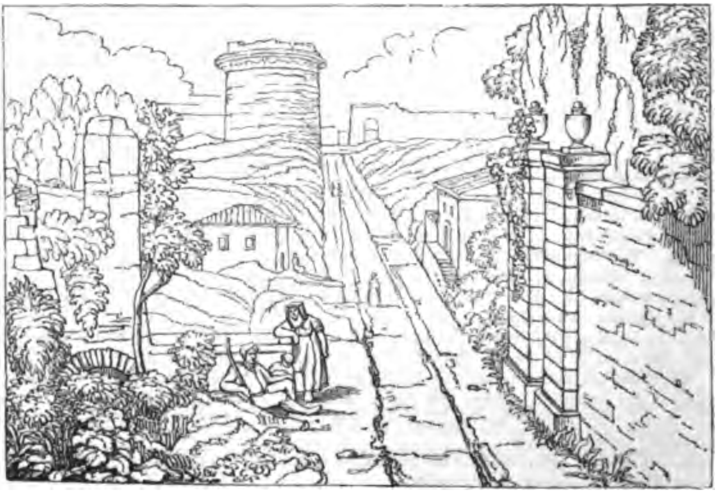

Fig. 828.

and 828. is from a spot a little way out of Rome, the tower of Cæcilia Metella being seen in the distance. In *fig.* 826. the masses are roughed in from the objects themselves; and the principal mass *abc*O1*d* on the left side is first very carefully drawn by itself, being, as respects leading lines and thicknesses, corrected until the eye is satisfied of the truth of its general form. The eye is as high as E and E, which therefore show the height of the horizontal line, and are also, in fact, the vanishing points for the wall on the right-hand side of the picture, and the house on the same side a little beyond it. Holding the port crayon level, and taking on it with the thumb or forefinger the distance O1, we shall find that twice that measure in 2 and 3 will give the junction of the wall with the pier; and that a line continued horizontally from *d* cuts the top of the plinth of the gate pier. The picture happens to be divided into two equal parts by a vertical line drawn through the break in the city wall in the distance. *d* 1, continued upwards, determines one side of the house on the right-hand side of the road, and from a point at a break in the foreground intersects the projecting wall at *e*: a vertical line determines the left side of the tower. The remaining horizontal lines, it will be seen, determine other points and lines; and thus it is manifest that the whole arrangement has been accomplished by making the mass *abc*O1*d* a measure or unit for ascertaining the size and relative position of the other parts. In *fig.* 828. the detail is filled in, and brought to a higher state of finish.

Sect. II.

PERSPECTIVE.

2405. A perspective delineation is the linear representation of any object or objects, as it or they appear to the eye, and is such a figure of an object as may be supposed to be made by a plane making a section of the body or pyramid of visual rays directed from the eye to the different parts of the object. A delineation so made, being properly coloured and shadowed, will convey a lively idea of the real object, and at the same time indicate its position and distance from the eye of the observer.

2406. Definitions. — 1. *An original object* or *objects* is or are an object or number of objects proposed to be delineated: for instance, a house, a ship, a man, or all or any of them together. In *fig.* 829. the house ABCDFHK is the original object.

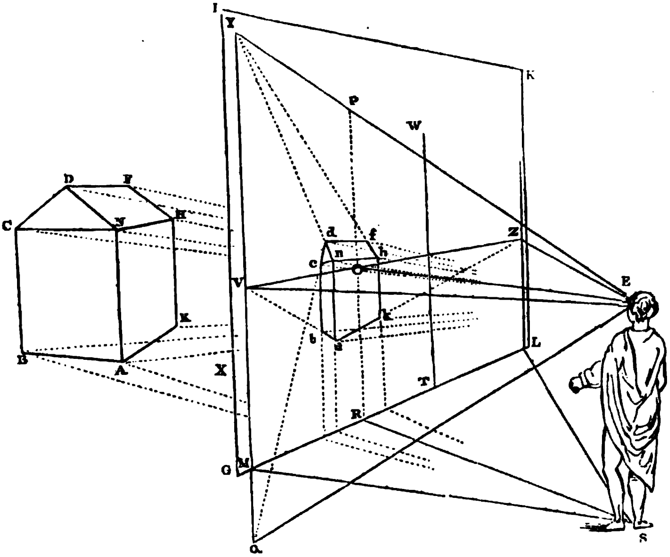

Fig. 829.

2. *Original lines* are any lines that are the boundaries of original objects, or of planes in those objects. The lines AB, BC, CD are original lines, being partly the boundaries of the original object ABCDFHK.

3. The *ground plane* is that upon which the objects to be drawn are placed, and is

always considered a boundless level plane. The plane X in the figure is the ground plane, upon which is placed the object ABCDFHK.

4. *The point of view* or *point of sight* is the fixed place of the eye of the observer, viewing the object or objects to be delineated: E in the figure is such point.

5. *The station point* is a point on the ground plane, perpendicularly under the point of sight or eye of the observer, and expresses on the plan the station whence the view is taken. S is the station point in the figure, being a point on the ground plane vertically under the eye of the observer at E.

6. *The plane of delineation* or *the picture* is the canvas or paper whereon it is intended to draw any object or number of objects. Thus, in the figure, the plane GIKL is the plane of delineation; but, in the extensive sense of the word, the plane of delineation is considered a boundless plane, however circumscribed may be the delineation made thereon.

7. *The horizontal line* or *the horizon* is a line on the plane of delineation in every part level with the eye of the observer or point of view. VZ is the horizontal line on the plane of delineation GIKL. It is supposed to be obtained by the intersection of a plane passing through the eye of the observer, parallel to the ground plane, produced till it touches the plane of delineation.

8. *The centre of the picture* is a point perpendicularly opposite the eye of the observer, or point of view, and is consequently always somewhere in the horizontal line. O in the horizontal line VZ is the centre of the picture, being perpendicularly opposite to the eye at E.

9. *The vertical line* is a line drawn through the centre of the picture perpendicular to the horizon. In the figure PR is the vertical line. It is here worthy of notice that the vertical line determines how much of the view lies to the right and how much to the left of the eye of the artist.

10. *The distance of the picture* is a direct line from the eye to the centre of the picture. EO is the distance of the picture, or plane of delineation, GIKL.

11. *The ground line* is that where the ground plane intersects the plane of delineation, as GL in the figure.

12. *An intersecting point* is one made on the plane of delineation, by producing a line in an original object till it touches the plane of delineation. Thus, T is the intersecting point of the original line BA.

13. *An intersecting line* is one made on the plane of delineation, by producing any plane in an original object till it touches the plane of delineation, or where, if produced, it would touch it. Thus WT is the intersecting line of the original plane ABCDN, being the line, where that plane, if produced, would touch the plane of delineation.

14. *A vanishing point* is that point on the plane of delineation to which two or more lines will converge, when they are the perspective representations of two or more parallel lines in an original object, whose seat is inclined to the plane of delineation. The point V in the figure is the vanishing point of the line AB, being found by the line EV, drawn from the eye of the spectator parallel to it, and produced till it touches the plane of delineation in the point V. For a similar reason, V is the vanishing point of the line CN; it is also the vanishing point for any other line parallel to the line CN, as BA; all parallel lines having the same vanishing point. The point Z is the vanishing point of the line AK, being obtained by a line drawn from the eye parallel to the line AK, and produced till it touches the plane of delineation. The point Z, moreover, is the vanishing point of the original lines DF and NH. And it is to be recollected by the student, that there will be as many different vanishing points of lines in the delineation of an original object as there are different directions of lines in that original object. The point Y is the vanishing point of the parallel original lines DN and FH, being found by the line EY being drawn from the eye parallel to them till it touches the plane of delineation. So also Q is the vanishing point of the line CD. In the process of perspective delineations, as we shall presently see, the plan of the object being drawn, the places of the various vanishing points are found on the ground line, whence they are transferred to the horizontal line by means of perpendiculars raised from them.

15. *A vanishing line* is one supposed to be made on the picture by a plane passing through the eye of the observer parallel to any original plane produced till it touches the picture. The line VZ is the vanishing line of an horizontal plane, and of all horizontal planes, being found by the intersection of a plane passing horizontally through the eye, or parallel to an horizontal plane. The vertical line YVM is the vanishing line of the original vertical plane, ABCDN being the line where a plane passing the eye of the spectator parallel to that plane would touch the plane of delineation. There will be as many different vanishing lines on the plane of delineation as there are different positions of planes in the object or objects; and

all parallel planes will have the same vanishing line. Similarly, all lines lying in the same plane will have their vanishing points in the vanishing line of that plane. All planes or lines in an original object which are situated parallel to the plane of delineation can have no vanishing lines or vanishing points on the plane of delineation.

16. *A visual ray* is an imaginary right line, drawn from the eye to any point of observation. EA and EY, &c. are visual rays, being right lines drawn from the eye to the points A and Y. Hence a number of visual rays directed to every part of an object will form a pyramid of rays, whereof the eye is the apex, and the object the base.

17. *A perspective delineation*, then, is the section of a pyramid of rays producing a perspective projection, and is most commonly considered as being made between the object and the eye. But the section of rays may be taken when they are extended beyond the object; in which case such a section is called a *projected* perspective representation of the object.

2407. It will then be seen that a knowledge of perspective is, as Addison has said, a knowledge of "the science by which things are ranged in picture, according to their appearance in their real situation."

2408. The situation of the objects being given with the plan and position of the plane of delineation and the height and distance of the eye of the observer, the delineation of such objects is truly determinable by rule. The mechanical operations necessary for this purpose form the subject of what follows. It is however necessary, before proceeding to lay them before the reader, to premise that he must thoroughly study and understand the preceding definitions before he can proceed with profit to himself, and we recommend a repeated perusal of them until that be effectually accomplished.

2409. Example I. In *fig.* 830., No. 1., we have the plan of the original object EBADCF, whereof ABCD is a cube, and BCEF a double cube, that is, twice the height of CBAD. GL is the plan of the ground line; S, the station point. Through S draw XY parallel to the plane of delineation GL, and draw SG and SL respectively parallel to the sides EA and AD of the united cubes ABCD and BCFE; and these produced to meet

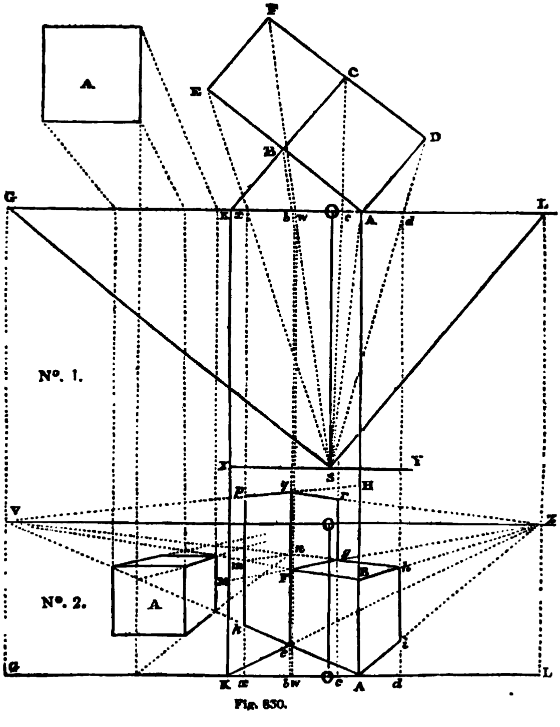

Fig. 830.

the plane of delineation will determine the vanishing points (Def. 14.) of the horizontal lines AE and AD, and of all other horizontal lines parallel to them. Draw the line SO perpendicular to GL, which line being the direction of the eye perpendicular to the plane of the picture determines the point thereon to which the eye should be directly opposite to view it when completed, showing also how much of the object is on one side, and how much on the other of the point of view. We have now to draw the visual rays SA, SB, SE, SF, SC, SD, cutting the plane of the picture or delineation in *b*, *x*, *w*, *c*, and *d*; the point A of the nearest cube touching, itself, the picture at that point. The preparation on the plan is now completed.

2410. The picture (No. 2.) or plane of delineation is to be prepared as follows: — First draw the ground line GL, and to such ground line transfer, by dropping verticals, the points K*xbwc*A and *d*. Above, and parallel to GL, at such convenient height as may be necessary to show more or less of the upper surfaces of the cubes or otherwise, as desired, draw the horizontal line VZ; mark on such horizontal line the point O, to which the eye is supposed to be perpendicularly opposite for viewing the delineation when completed. All the other preparations are obtained from the plan, and may be obtained as follows: — First set off on the horizontal line VZ the points V and Z, which are the vanishing points of the sides AE and AD respectively. As A, the nearest angle of the object, touches the plane of delineation, it is manifest that a line vertically drawn from that point will be of the same height as the object itself, that is, as the figures are cubes, equal to AB or AD in the plan No. 1. Take, therefore, AB No. 2. of the height required, and draw the lines BV and AV, also AZ and BZ, which being crossed by verticals carried up from *xbwcd* will determine the points *ke* and *i* at the bottom, and in *f* and *h* at the top, and *pq* and *r* in the part where the cube is double the height. Drawing *h*V it is intersected by the verticals from the visual rays at *c* and *w*, cutting in *g* and *n*. The line KK forms another line of heights, if desired, for finding the height F*q*; indeed, by continuing any line BC (No. 1.) to K, intersecting the picture, a line of height may be obtained. The representation of the cube marked A will be understood without difficulty, if what has preceded be well comprehended. As by Definition 15. we have seen that all planes or lines in an original object situated parallel to the plane of delineation have no vanishing lines or points in the plane of delineation, so two of the sides of the cube will be bounded by horizontal and vertical lines, inasmuch as those sides lie parallel to the plane of delineation. The vanishing points for the other lines will of course be found in O, which passes through the picture at right angles to it from S, the station point.

2411. Example II. To find the representation of a quadrangular building, situated inclined to the picture, covered with a single spanned roof, having a gable at each end.

2412. Let the rectangle ABCD (No. 4.) (*fig.* 831.) be the plan of the building, the line EF will be the place of the ridge of the roof extending from end to end. Let the line QL be the place of the plane of delineation, and let S be the station point.

2413. Find O the centre of the picture, also the points Q and L, the vanishing points of the lines AB and AD, and their parallels, by lines drawn from S parallel to such lines, and intersecting the picture. Produce the face of the building AD to I for an intersection with the picture, and draw the visual rays intersecting the ground line of the picture in the points *beaf* and *d*. These need not, however, be drawn beyond the plane of delineation.

2414. Prepare the picture (No. 5.) by drawing the horizontal and ground lines VZ and GR at any distance from each other at pleasure; fix upon the centre of the picture O, and draw the vertical line OO; set off the distances of the vanishing points OV and OZ, equal the distances of the vanishing points OQ and OL in No. 4. Draw the intersecting line IL (No. 5.), and all the visual lines, through the points *beaf* and *d*, taken from their respective places and distances *beaf* and *d* (No. 4.), and proceed as follows: —

2415. On the intersecting line IL (No. 5.) set up the height IK equal to the height of the building BC or HG (Nos. 1. and 2.), and draw the lines KZ and IZ, determining the plane *gmop* for the front of the building. Draw the lines *m*V and *g*V, determining the end of the building *ghim*. It now remains to place the roof, which is readily done, but which, however, requires some circumspection in the process.

2416. Place the height of the roof XD (No. 1.) on the intersecting line at IL (No. 5.), and draw LZ, which will give the height of the roof on the angular line of the building *gm* at *r*; from which spot it may readily be transferred to its proper place in the visual line *ek* by the line *r*V, which cuts the line *ek* in the point *k*, the point required. From the point *k* draw the lines *ki* and *km*, completing the gable end of the building. Draw the ridge of the roof *k*Z, cutting the end visual line, in the point *n*; and lastly, draw the line *no*, completing the whole linear delineation of the building *ghiknop*. It is to be observed, that whatever original plane is produced to the picture to obtain an intersection, such intersection serves only to obtain heights in the direction of that plane; whence they may be transferred to other planes in contact with it, as in the present instance. The intersecting line IL (No. 5.) is the intersecting line of the plane *gmop*; hence any original height set up

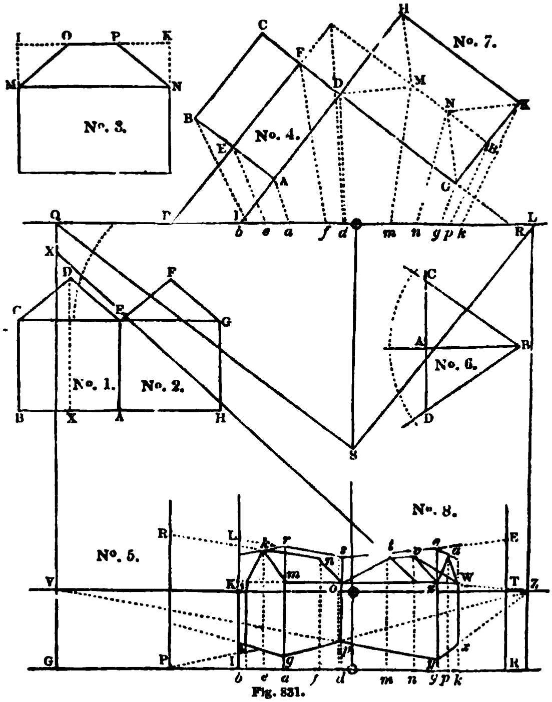

Fig. 831.

thereon can only be transferred throughout the direction of that plane. Thus the height of the roof IL was transferred by the line LZ along that plane to its other extremity *s*; but the line *rs* is not the place of the ridge of the roof, which lies in the middle of the plane *ghikm*, proceeding from the point *k*; but any height on the angular line *gr* is easily transferred along that plane by means of its horizontal vanishing point V, by which means the height of the roof was obtained by the line *r*V at *k*. If, instead of the plane over the line AD (No. 4.) being produced for an intersection, the plane of the middle of the house in the direction of the ridge of the roof had been drawn, and the height of the roof had been set up on that line, it would at one application be transferred to its proper place.

2417. Let the line FE (No. 4.) be produced to P for an intersection, set off the distance OP at OP (No. 5.), and draw the intersecting line PR. On PR set up the height of the ridge of the roof equal XD (No. 1.), and draw the ridge line RZ, and it determines the exact ridge of the roof between the proper visual lines, and will be found to correspond exactly with the ridge obtained by the former process.

2418. The roof may, however, be found by another process, thus:—The slant lines of the roof have their vanishing points on the picture as well as any other direction of lines in the same object. The line *km* (No. 5.) being in the vertical plane *ghikm*, will have its vanishing points somewhere in the vanishing line of that plane. (Def. 15.) A vertical line drawn through the horizontal vanishing point V will be the vanishing line of the plane *ghikm*; therefore the vanishing point of the lines *km*, *ki*, and of all lines parallel to them, will be somewhere in the vertical GVXQ.

2419. Two lines drawn from the eye parallel to any two lines in an object, finding their vanishing points, will make the same angle at the eye as the lines in the object make with each other; for the two lines in the one instance are respectively parallel to the two lines in the other.

2420. The line SQ is drawn from the station S parallel to the line AB (No. 4.), and a line drawn from the station S, making the same angle with SQ as ED does with EC, (No. 1.), will find the vanishing point of the line ED, and this point must be evidently somewhere in a vertical line through the point Q. To obtain this point in practice, take the distance of the vanishing line it is in, that is, the length from S to Q in the compasses, and set off the same in the horizon (No. 5.) from V. to W. At the point W make an angle VWX equal to the inclination of the roof, that is, equal to the angle CED (No. 1.), and produce the line till it intersects the vertical line through the vanishing point V in the horizon in the point X. The point X will be the vanishing point of the line of the roof *km* (No. 5.), and of the line *no*, parallel to it. The slant lines of the roof *km* and *no*, already obtained, will, on application of a ruler, be found to tend to the point X, as above stated.

2421. In the same way the line of the roof *ki* (No. 5.) will also have its vanishing point, and in the same vertical line GVQ. It will be found to be as much below the horizontal vanishing point V as the point X is above it. (Def. 14.)

2422. Let the line AB (No. 6.) be the line of the horizon, and CD the vanishing line of a vertical plane, being the gable end of a house, and let the angle ABC be that of inclination, finding the vanishing point of the slant lines of a roof in one direction. Let the line BD be the line, finding the vanishing point of the slant lines in the other direction, having the same inclination to an horizontal line; then the angle ABD will be equal to the angle ABC, and the distance AD equal to the distance AC.

2423. Example III. To find the representation of a quadrangular building situated inclined to the picture, covered with a single hipped roof.

2424. Let the quadrangle GDHK (No. 7.) be the plan of the building; the line MN will represent the ridge of the roof. The former line QL may be the place of the plane of delineation, and it may be viewed from the same station S. The position and direction of the lines of this object being the same as those of the last example, the preparatory lines will also answer for this. We have then only to draw the visual rays MS, NS, CS, PS, and KS, intersecting the picture in the points *m*, *n*, *g*, *p*, and *k*, and to produce the line DG for an intersecting point at R.

2425. Prepare the picture (No. 8.); let the line VZ be the horizon, GR the ground line, O the centre of the picture, and the points *m*, *n*, *g p*, and *k* coresponding with *m*, *n*, *g*, *p* and *k*. (No. 7.) Draw the visual line lines through those points and the intersecting point R, and proceed as follows: —

2426. On the intersecting line RE set up the height RT, equal the height of the object HG (No. 2.), and draw the lines TV and RV, cutting the visual lines of the front of the building in the points *z* and *o*, *y* and *p*, determining the plane *ypoz* for the representation of the plane of the front. From the angular points *z* and *y* draw the lines *zw* and *yx* to their vanishing point Z determining the plane *yzwx* for the end of the building.

2427. On the intersecting line set up the height of the roof TE equal the height NK (No. 3.), and draw EV cutting the angular visual line of the building in the point *e*, from which point draw the line *ez*, cutting the visual line *pa* in the point *a*, the point of direction of the ridge of the roof. Draw the line *a*V, which, cutting the visual lines through the points *m* and *n* in the points *t* and *v*, determines the exact position of the ridge of the roof *tv*, which is the representation of OP (No. 3.), or of the ridge MN (No. 7.); draw the lines *to*, *vz*, and *vw*, which will complete the whole representation required. In No. 8., if the lines *az* and *aw* be drawn, they will form a gable end *yzawx*, of which the point *a* is the point of the gable, and will answer for the direction of the ridge, whether it be a gable end or a hipped roof, for in both cases it lies in the middle of the breadth of the house; wherefore the line *a*V answers as well the edge of a hipped roof as of a gable end.

2428. In examining the plans (Nos. 4. and 7.) of the two buildings, it will be seen that they are placed at right angles to each other, and in contact at the point D, so that the second example might have been easily accomplished from the first, without the aid of another intersection and other preparatory lines, than the additional visual rays from the angles, which the student will have surely no difficulty in carrying through, without the necessity of encumbering these pages with the detail.

2429. Example IV. In *fig.* 832. No. 1. is the general plan of a church similar to many country churches. ABCD is the main body of it; EFGH its tower; IKLM and MLNO subordinate parts of the building, and *abcd* the porch. No. 2. is its geometrical elevation; the ends and measurements, AB and BC, answering to IM and MO in No. 1., and the points of the roofs D, E, and F. (No. 2.) answering to the lines of the ridges QR, TV, and PL, No. 1. To find the perspective representation of this building on the plane of delineation YZ, the station being at S, the following is, perhaps, the readiest process.

2430. Find the vanishing points Y and Z of the horizontal lines of the building by the lines SY and SZ being drawn from the station parallel to them. O is the centre of the picture. Draw the visual rays from the visible angles of the object in direction to the station S, to intersect the plane of delineation.

2431. When a complicated object, that is, one composed of many parts, is to be drawn, it requires, of course, a great number of visual rays for the precise determination of those parts, and the whole together forms an apparently confused number of lines. The eye, however, which views them properly, does not perceive that confusion; and, if it perplex the student, different coloured inks, or of different shades of depth, may be used to particularise different parts. In the delineation of such an object as the present example, the most important consideration is the choice of a proper intersection; for though any inter-

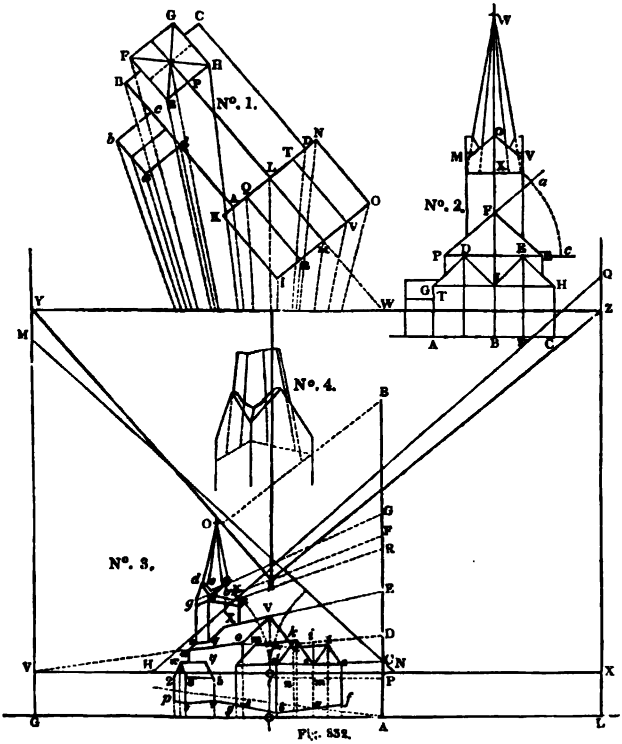

Fig. 832.

section will do, that should be chosen which unites most parts in its direction with the greatest exactness and the least trouble. In the case under consideration, none seems more eligible than the direction of the roof PLM, which produce to W.

2432. In the picture No. 3., GL is the ground line, GV the height of the horizon, the line VX being then the horizontal line. O in the horizon is then the centre of the picture, from which, place the distances of the horizontal vanishing points OV and OX equal OY and OZ, No. 1. AB (No. 3.) is the intersecting line, and all the visual lines on the plane of delineation are drawn conformably to their intersections on the ground line in the plan. On the intersecting line the height AC is made equal to the height AG of the elevation No. 2.; and the lines C*c* and A*a*, being drawn in direction to the vanishing point V, determine the height *ac*; being the height of that part of the building on the visual line answering to the ray from the point M in the plan No. 1. Through the points *a* and *c* draw the lines *de* and *bf* to their vanishing point X, determining the plane *bdef*, the representation of the plane AGHC, No. 2.; the visual lines *bd* and *fe* answering to the rays from the points I and O in the plan. Draw the lines *dh* and *bg* tending to their vanishing point V, to the ray from K in the plan completing the plane *bghd*. On the intersection make the height AD equal to the height of the roof NE of the elevation No. 2., and draw D*i* in direction to V. Through *i* draw the line *kl* to the vanishing point X, touching the visual lines of the roofs in the points *k* and *l*. Draw the lines *km*, *mh*, *kd*, *kc*, *lc* and *le*, which will complete the whole of the structure over the plan IKNO, No. 1.

2433. The height of the roofs of the low buildings is equal to the height of the upright walls of the body of the building, as shown by the line PR in the elevation No. 2.; hence, the line *mo*, and the return line *on*, may be drawn to the visual lines corresponding with the intersections from the angles A and B of the plan. From the angle *g* the line *gs* may also be drawn, which will determine the lines *sr*, *rt*, and *tp* of the porch. Make AE on the intersection equal to the height of the roof BF in the elevation, and draw the line EV determining the ridge of the roof between the two visual lines from the points P and L of the plan. Draw the lines of the gable end *vo* and *vz*, the point *z* being obtained by the line *om* drawn to its vanishing point X, cutting the visual line from the angle D of the plan in the point *z*.

2434. Make AG and AF on the intersection equal to the heights of the tower BO and BM of the elevation, and draw the lines GV and FV cutting the visual line from P in the plan, in the points *a* and *b*; through which points draw the lines *ac* and *ef* to their vanishing point X; and the lines *cd* and *eg* to their vanishing point V; the points *g*, *e*, and *f* being in the proper visual lines from the angles of the tower F, E, and H in the plan. The tower will be completed by drawing the lines *dg*, *de*, *ae*, and *af*.

2435. This example elucidates the general practice of vanishing points, which are as well to be obtained of other positions of lines as horizontal ones. It is not always that the vanishing points of inclined lines are required, but they are often useful, and sometimes absolutely necessary. In the geometrical elevation No. 2. the lines MO, PF, GD, IE are all parallel lines, as also are the lines OV, FR, EH, and DI, and though situated in different, yet they are in parallel planes, and will therefore have a common vanishing point. A line drawn perpendicularly to the horizon through the vanishing point X (*fig.* 3.), as LQ, will be the vanishing line of the plane of the end of the church over the line IO of the plan, also of the end of the body AD, likewise of the side of the tower EH; and a line drawn through the point V (No. 3.) perpendicularly to the horizon, as GM, will be the vanishing line of the planes over the lines (No. 1.) IK, AB, *ab* of the porch, and FE of the tower, and all lines in those planes, or the boundaries of those planes, will have their vanishing points somewhere in those vanishing lines.

2436. To obtain the vanishing points of the inclined lines of the roofs and tower, take the distance of the vanishing point Z from the station S in the compasses, and apply it on the horizon from X to H. At the point H make an angle with the horizontal line equal the angle of the roofs *a*P*c* (No. 2.); the curve KI and the distance of it from the centre H being equal to the curve *ac*, and distance of it from its centre P: then is the angle KHI equal to the angle of the roof *a*P*c* (No. 2.). Produce the line HK to Q; Q will be the vanishing point of the line *ea* of the tower, also of the parallel lines *ov*, *dk*, and *cl*, which, though obtained by a different process, will all be found, by application of a ruler, to tend truly to that point, as is shown by the dotted lines in the example. Proceeding in the same way with the distance of the vanishing point Y from the station S, we obtain the vanishing point of the same inclination of lines in the other planes of the object. Take the length SY in the compasses, and set it off on the horizon from V to N. At the point N make an angle INT on the horizon equal the angle KHI, that is, equal the angle of inclination of the roof *a*P*c* (No. 2.). The line NT produced to M in the vanishing line GM will be the vanishing point of the line *de* of the top of the tower, also of the lines *w*3 and *y*5 of the porch (the inclination of the roof of the porch being the same as the other roofs of the body of the church), as shown by the dotted lines in the example. The walls of the porch are obtained from the height AP on the intersection, equal the height AT, No. 2., P*m* being drawn to the vanishing point V, and *mn* to X, give the lines *n*5, 53, and 32. We may observe that the inclined lines *af*, *le*, *kc*, and *vz* have a common vanishing point, which, if required, may be obtained; it will be in the same vanishing line with the point Q, and as much below the horizontal vanishing point X as the point Q is above it, to which point, were it obtained, the lines already drawn will be found exactly to tend. It is seldom absolutely necessary to have both those points; in this instance one only of them, the point Q, is obtained, which answers every end required of both; for, supposing it were left to that vanishing point for finding the inclined lines, the visual lines being drawn, and the heights of the upright walls being found, the line *dk* being drawn in direction to the vanishing point Q determines one side of the gable end at the visual line in the middle; the other is accomplished by joining the points *k* and *c* together. So of the other gable, *cl* being drawn, *le* is also had by joining together the points *l* and *e*.

2437. To complete the whole, draw the line *xq* on the tower from the point *x* to the angle of the tower, in direction to the vanishing point Q; then draw the lines *qh* and *nh* to their proper visual lines and vanishing points V and Q. The putting on of the spire requires some consideration, and in it we must proceed with some thought and care. The base of it is intended to be a regular octagon. If the two external lines in the geometrical elevation of the spire be continued till they touch the sides of the tower, as is done at K and L (No. 2.), and an octagon be there constructed, extending the square of the tower, it will be the base of the spire. Set up the height of the spire BW (No. 2.) on the intersection (No. 3.) at B; also the height of the base line KL at R, and draw the lines BV and RV; the first, cutting the visual line through the centre of the tower in the point O, determines the height of the spire; the other, cutting the tower in the point *u*, determines its base. Through the point *u* draw a line round the lower, and find the points of the octagon in the middle of each face of the tower, to which let lines be drawn from the top O, and the whole will be completed, as shown in the example.

2438. Thus have we gone through the process of finding the representation of rather a complicated object with as little confusion of lines as possible; but one thing succeeding another, and each being required to remain for the student's observance, the whole unavoidably becomes intricate. Indeed, it is not now so perfectly executed but that something remains for the student to complete, which must result from his own study or occupy more space than all we have already written on it. We allude to the intersections that take place at the lodgment of the spire on the top of the tower, to elucidate which it is drawn to a larger scale at No. 4., the mere inspection whereof will convey a full and, we hope, satisfactory idea of what we advert to. The student has been left to complete the base of the octagon, a process so simple that we cannot, if he retain what he has read, believe he will find difficulty in accomplishing, either by visual rays or otherwise. It is next to an impossibility to describe intricate matters like these so as to leave nothing for the exercise of the reader's judgment; for, however copious the instruction, there will always remain sufficient unexplained to keep his mind in action, and afford him the opportunity of exercising his own ingenuity.

2439. Example V. In *fig.* 833. the objects X and Y are plans of columns with bases and capitals, whose general forms are shown at X and Y (No. 1.). YZ, as before, is the plane of the picture, S the station point. The picture, as previously, is prepared with the vanishing points VZ, and the ground line GL. OO is the central line of the picture, and BA, BA are, it will be seen, lines of height.

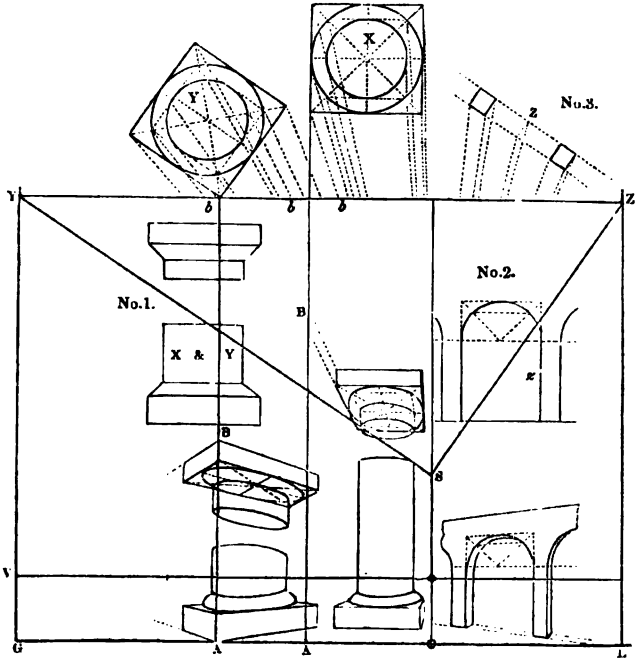

Fig. 833.

2440. In the squares X and Y the dotted lines show the diagonals and boundaries of squares inscribed in the circles, by which so many more lines are gained for obtaining the curves which the circles form in the perspective representations. The visual rays are drawn as in the preceding examples, and transferred to the picture, the process being, in fact, nothing more than making squares following the profiles, which, at the different heights, guide the formation of circles within and around them, of which the upper ones only, for preventing confusion, are shown in the perspective representation. In each series, the extreme width of the appearance of the circle may be obtained by visual rays, as at *b*, *b*, *b*.

2441. At Z and *z* (Nos. 3. and 2.) are the plan and elevation of an arcade, from which it will be seen that the principle of inscribing squares and diagonals is equally applicable to the vertical representation of circles. Presuming that we have sufficiently described the diagram to enable the student to proceed in drawing the examples at large, we shall now submit an example of general application.

2442. Example VI. In *fig.* 834. YZ is the plane of delineation, and the plan of the building, with its projections, roof, and chimneys, is shown in No. 1. In practice, this is generally made on a separate drawing board, to enable the draughtsman to make his perspective

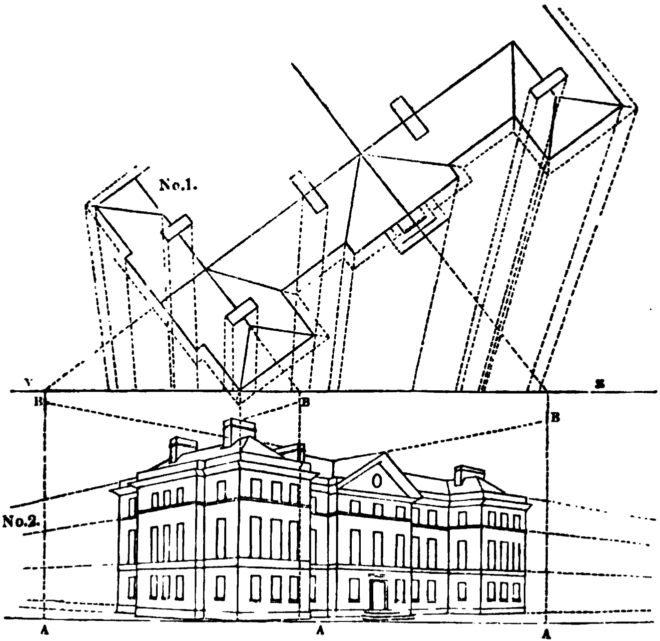

Fig. 834.

outline without injury from constantly working over the paper. Here the vanishing points are too distant to be shown on the diagram; but the reader, from the tendency of the several lines, will easily find where they lie. In the same manner, he will find whereabout the station point is placed. BA, BA, BA, No. 2., are lines for the transference of the heights. The projection of the cornice is dotted round the leading lines of the building on the plan. The rest of the figure cannot fail of being understood and put in practice by the student who has made himself master of the preceding examples.

2443. We shall now turn to a point whereon much difference of opinion has prevailed, namely, the adjustment of what may generally be considered the best angle of vision, within which objects should be seen to obtain the most agreable representation of them. For as this angle is enlarged or decreased by viewing the objects at greater or less distances, their appearance will vary, and their delineation, in consequence, be affected thereby, and distortion of the objects will be the result.

2444. By the angle of vision or angle of view is understood the expansion of the lines proceeding from the eye, by the two extreme visual rays embracing the whole extent of the view, and this whether it consists of one object or of many. Let A (*fig.* 835.) represent the plan of a mansion; let B be the outhouse contiguous to the mansion, and let the places of trees be at CCC and DDD. Let S be the station or point of view from which the whole is seen. Considering the mansion A as a lone object, the extreme visual rays S*a* S*b* form at the eye the angle *a*S*b*; then *a*S*b* is the angle of view under which that object is seen, S*a* and S*b* being the two extreme visual rays embracing the whole extent of the object. Again, if the outhouse B be taken as a single object, then will the extreme visual rays *c*S and *d*S form, at the eye, the angle *c*S*d*, being the magnitude of the angle under which that object is seen. So of any object, the visual rays that embrace its whole extent form the angle of view under which it is said to be seen. It is then manifest that the angle of view will be either large or small, as the eye is near to or remote from the object. Suppose both the objects A and B are to be taken into the view, with the ad-

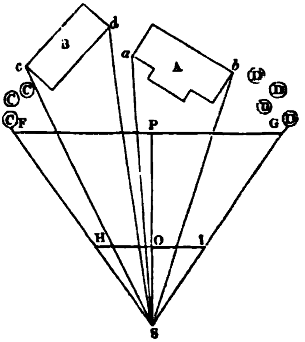

Fig. 835.

dition of the trees to their right and left. Let visual rays be drawn from the trees on both sides to the station S. The angle CSD is the angle of view under which the whole extent is seen, and the rays CS and DS are denominated the extreme visual rays of the view.

2445. Objects may not only be placed too near the eye for comfortably viewing them, but they may be so nearly placed to the eye as to give it pain. The eye only contemplates a small portion at a time; it is only by its celerity and continual motion that it becomes perfectly sensible of a whole and of the many forms whereof it is composed. But when an object, or many objects, widely extended, are placed too near, the traverses of the eye in viewing the whole become painful. Every one must have experienced that this is so, and why so we must leave to others to account for. When the eye is removed to an agreeable distance, the extent of the view to be delineated is at once seen without turning the head to one side or the other, so that all the objects are at once comprehended.

2446. In taking a view, the turning of the head is to be avoided. The view should on no account comprise a greater extent than can be taken by a *coup d'œil*, or than can be viewed by the traverse of the eye alone; and this necessarily confines the extent of that with which we have to deal, and brings the angle of view within certain limits. What the eye can contemplate without trouble it views with pleasure, and beyond a certain extent the eye becomes distracted.

2447. Smallness of object has no relation to the angle of view; a die, or the smallest possible object, may be brought so near the eye as to give pain in looking at it, and a large extent of view may be contemplated with as much ease as a small one, by merely placing the larger one at a greater distance. If the place of the plane of delineation be at FG, then FSG will be the angle of view. If a section of the same visual rays be taken at HI, then HI will be the extent of the picture, and the angle HSI is the angle of view; but the angles FSG and HSI are the same, therefore the eye views both with equal satisfaction: but in this case one must be placed at the distance SO, and the other at the distance SP.

2448. The attempt to select an angle suitable to all the cases that may occur, as the best angle of view, would be as vain as it would be absurd. Different subjects require different treatment. External subjects differ from internal ones; and the last from each other, according to circumstances. Some authors on the subject have laid it down as a rule, that the greatest distance of the eye from the picture should not exceed the width of the picture laterally, which makes the angle of view about 53 degrees; others have insisted that the distance should be less, requiring that the angle of view should not be smaller than 60 degrees; and others allow of a still larger angle. The elder Malton, and his son, to whom we are indebted for all that is valuable in this section, and whose (both of them) experience in the matter was very extended, advise that the angle of view should never exceed from 53 to 60 degrees; the former recommending an angle of 45 degrees as the best, because neither too large nor too small. The elder Malton advises to keep between the one and the other, that is, not to let the angle of view exceed 60 degrees, nor be less than 45, the first being likely to distort the objects, and the last rendering them too tame in the outline. We can add, from our own experience, that the advice is sound; for though, under very particular circumstances, it may be necessary to use a larger angle of view than 60 degrees, such a case does not frequently occur. Much must always be left to the discretion of the artist in respect to points which are to guide the angle of view he adopts. After a little experience, he will find that angle best suited to the circumstances under which his drawing is to exhibit the object or objects.

2449. Example VII. The principles upon which we delineate any of the interior parts of a building are in no wise different from those used for the representation of their external views, for it is of course immaterial whether we represent the external faces of their sides, or those which form their internal faces; the only difficulty which arises in making an internal view being that which arises from the inability, on account of the restricted distance under which they are in reality viewed, of placing the station point at such a distance as to take in a sufficient quantity of the objects to be represented. A person placed in a room can of course only see the whole of one and part of another wall; in short, in every direction he cannot see comfortably more than, as we have above mentioned, forty, or, at the most, fifty, degrees of the objects around him. On this account, and for the purpose of showing more than in reality can be seen, it is customary, and perhaps justifiable, in order to give a more comprehensive view of the interior to be delineated, to place the station point of the spectator out of the room or place, supposing one or more of its sides to be removed. This is, in fact, a delusion, as is every view of an interior possessing any merit that has come under our notice. But for picturesque delineation, it is not only one which is necessary, but one without the practice whereof no satisfactory representation can be given of an interior whose dimensions are not very extended. The section whereon we are now engaged is not supposed to be a treatise on Perspective, but merely a general developement of its principles so as to give the reader such a general knowledge of the subject as may enable him to pursue it, if he please, from the hints it affords. With this apology for not producing to him a more complicated, though not less useful subject, we proceed.

2450. *Fig.* 836. (No. 1.) represents the plan of a staircase one third the size used for the purposes of the delineation; YZ (No. 1.) is the plane of the picture, O is its centre. From the data, therefore, there will be no difficulty of obtaining the vanishing points of the sides Y*a* and *ab*. The diagram is not encumbered with the visual rays necessary for the delineation, which we are to suppose drawn and transferred to their proper places on No. 3., wherein HH is the horizontal line. No. 2. is a longitudinal section of the staircase, wherein are shown the rising and descending steps, and the dotted line *cd* gives the section of the vaulted ceiling over the staircase. It will be immediately seen that the ends of the steps will be determined by visual lines, notwithstanding the ascent and descent of them, because either is determined by referring to any lines of height, which may be obtained from the plan and section, by which the portions seen of the flights will be immediately found and

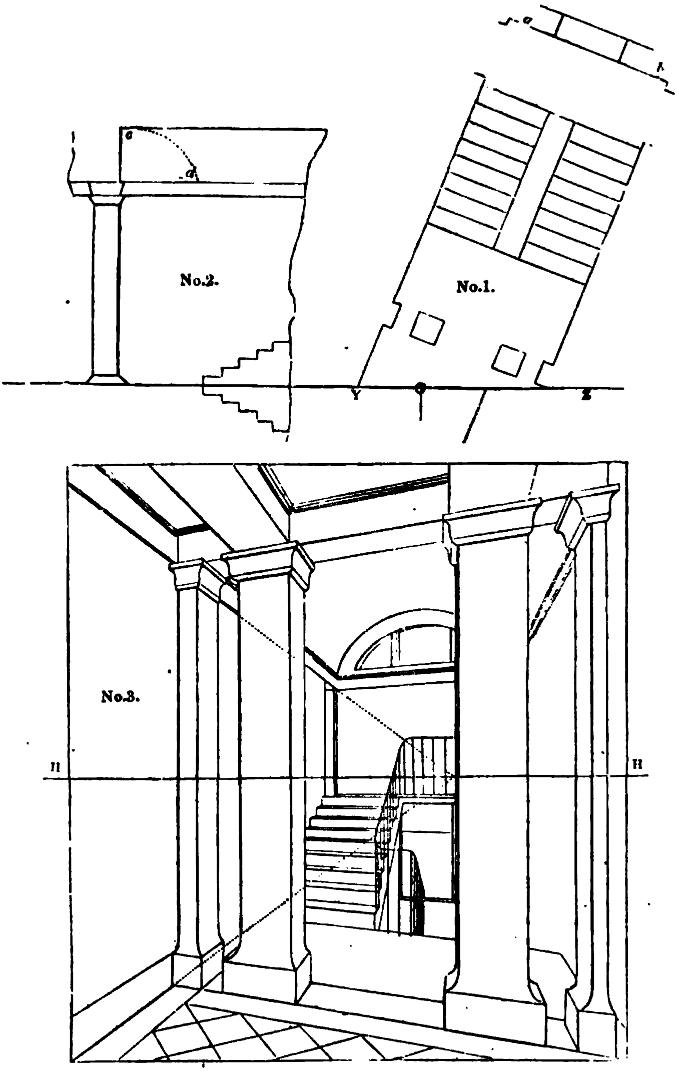

Fig. 836.

transferred to their respective places on the picture. With these observations we leave the diagram for the exercise, on a larger scale than here given, of the ingenuity of the student.

2451. Example VIII. The last perspective example to be submitted is that of a cornice (*fig.* 837.), wherein the contrivance of the elder Malton is used for finding the places of the modillions and the other parts.

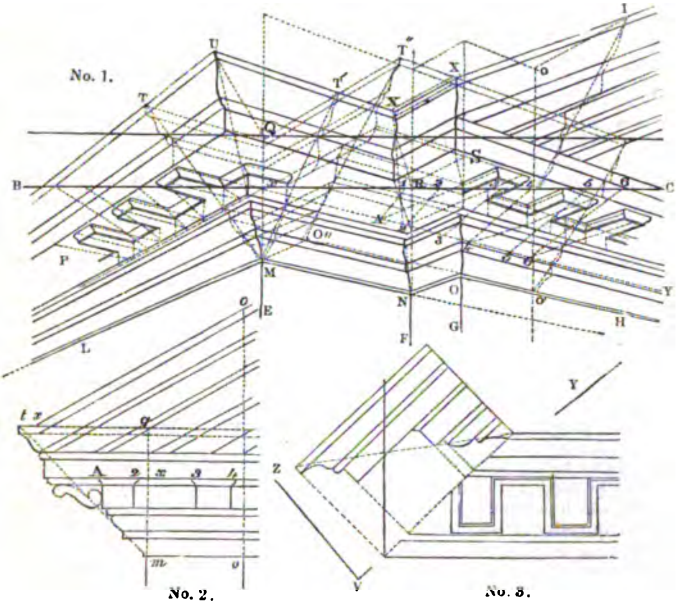
No. 1.
No. 2.
No. 3.

Fig. 837.

2452. Let EM, FN, GO (No. 1.) represent the angles of a building in perspective, LMNO being the lower horizontal line of the cornice, whose geometrical elevation and profile are shown in No. 2. Make MQ equal to *mq* the depth of the cornice, supposing the edge EQ to be in the plane of projection; draw PQRS, &c., the lines of the top of the cornice, to their respective vanishing points. Make QT, QT' in RQ, PQ, produced equal to the perspective projection of the cornice *qt*. Then place the depths of the various mouldings along MQ, and fix the lengths of their projections on the lines drawn to the vanishing points through those in EQ, an operation which may be much facilitated by drawing MT, MT', by which, in many places, the points of the mouldings are at once determined, as in the case of the top and bottom of the fillets of the ovolo; and very often, if the drawing is not on a very large scale, *mt* and its perspective images MT, MT', &c. will enable the eye to proportion the mouldings. Thus the perspective projections MQT, MQT' of the sections of the cornice by the planes of the sides EN, EL, supposed to be prolonged or extended, may be found; and it is manifest that lines through the points of these sections to the proper vanishing points will give the perspective forms of the cornice mouldings as they would appear.

2453. The lines found will by their intersections supply the mitre MQU; but where the scale is large, it is better to obtain mitre sections at each principal angle of the building as shown by the lines MQU, NRX, &c. The planes of the mitres form, of course, angles of forty-five degrees with the sides of the building itself, consequently the vanishing points of QU, RX, &c. may be found by bisecting perspectively the right angles found, or by drawing on the plan lines parallel to the diagonal lines or mitres from the station point to intersect the picture. If these, indeed, are found in the first place, there would be no necessity to draw the square sections MQT, MQT', inasmuch as lines drawn from the mouldings intersecting the mitre sections to the vanishing points will at once form the perspective representation of the cornice. In practice, this is the usual mode of proceeding, because a skilful draughtsman can pretty well proportion by his eye most mouldings as seen in perspective; but where great accuracy is required, the method of proceeding by square sections is recommended, because, from the great foreshortening of the diagonal line, the smallest inaccuracy of intersection on it will cause very large errors in the mouldings.

When the diagonal sections alone are used, it is clear that the geometrical profile, No. 2., will not be the same as that formed by the oblique section of the cornice: this last must therefore be obtained from a plan and elevation of the mouldings as shown in No. 3.

2454. Instead of finding the square section made by the plane FNGO at the angle OG, it may be drawn on the plane TQM, where it is more readily found by producing the lines whereby the section TQM was obtained: so the lines T′T″, MO″ are set out in perspective equal to the projection of the break of the building ON: moreover by the line T″O″ we may obtain the mouldings of the cornice on the face of the wall GH as produced or prolonged to T″O″, and conversely the cornice in perspective may be drawn from this imaginary section, if it be previously found.

2455. Our next care is to find the vanishing point of the raking mouldings, which may be found from what has already been said, and a perspective section must be made of these mouldings by means of any vertical plane where most convenient; but the best place is through the apex of the pediment, which, as it could not, for want of room, be done in the present example, is taken through the line *oo*, No. 2., passing through the extreme left angle of the tympanum of the pediment.

2456. As the mouldings of the pediment here are of the same depth and projection as in the horizontal parts, they will not, when inclined, coincide with the diagonal section of the horizontal cornice at OS; hence that section, if found in perspective at OS, cannot be used for drawing the perspective representation of the pediment cornice, except for the bead or fillet above the corona, which, from the construction of the pediment, will coincide at this mitre, as we may see in No. 2.; whence it may also be seen that the point *x* does not coincide with *t*. X′*x* cannot, therefore, in the perspective representation, be drawn through X, the point answering to *t* in the diagonal section NRX. OO′ in the line OH is to be made in perspective equal to *mo*, No. 2., and the whole depth *oo*, and those of the several mouldings on the oblique section, being set upon EQ produced, they are to be transferred to OO′ by means of the vanishing points. The distance O′I is the perspective distance of the projection *qt* of the cornice as before, and is most readily obtained from the section O″T″, which is transferred to the plane O′I, and will be easily comprehended from the figure, the quantity of projection of each raking moulding of the pediment is equal to that of the same moulding where horizontal. Thus the perspective representation of an oblique section made by a plane passing through *oo*, No. 2., is obtained, and the mouldings are then drawn to the vanishing point through the various points, the line IX′ cutting T″X in the point corresponding to *x*, No. 2. As to the modillions, their representations are found with less confusion by planning them apart and using visual rays; but if no plan is used, the following method, invented by the elder Malton, may be adopted: —

2457. Draw BC, the line intersecting the plane of the sofite of the corona, Nos. 2. and 3., through the proper point *x* in MQ at right angles to it, and draw *xy* to the vanishing point. Produce the line corresponding to A in No. 3. to A in *xy*, and transfer A to 1 in BC, so as to be proportional to it in respect of the whole extent. Then set off the proportional widths and intervals of the modillions, as shown on Nos. 2. and 3. on BC, and transfer them by means of the same proportioning point by which *x* was transferred to 1; and from the points 2, 3, 4, 5, 6, &c. in *xy* thus obtained, draw on the perspective of the sofite by the use of the vanishing point the lines representing the tops of the modillions corresponding to 2, 3, 4, &c., No. 2. The cymatium round them and the inner angle of the sofite may be drawn by the eye, or where great accuracy is required, the mitre or diagonal sections may be determined as for the principal mouldings already described. At the backs of the modillions the verticals are to be determined either by means of visual rays from a plan, or through the medium of intersections of the perspective lines of the upper parts of them on the sofite, which is as much as can be requisite for guiding us to a correct delineation. The same process is to be used for the modillions on the other sides.

Sect. III.

SHADOWS.

2458. Sciography, or the doctrines of shadows, is a branch of the science of projection, and some preparation has been made for its introduction here in Sect. VI. Chap. I. (1110, *et seq.*) on Descriptive Geometry, which, if well understood, will remove all difficulty in comprehending the subject of this section.

2459. The reader will understand that in this work, which is strictly architectural, the only source of light to be considered is the sun, whose rays, owing to his great distance, are apparently parallel and rectilineal. It is moreover to be premised, that such parts of any body as may be immediately opposed to the rays of light are technically said to be *in* *light*, and the remaining parts of such body are said to be *in shade*. But when one body stands on or before another, and intercepts the sun's rays from the latter, which is thereby deprived of the action upon it of the rays of light, the part so deprived of the immediate action of the light is said to be *in shadow*. It seems hardly necessary to observe, that the parts of any body nearest the source of light will be the brightest in appearance, whilst those furthest removed from it will, unless under the action of reflected light, be the darkest.

2460. It has been the practice, in architectural drawings, to represent the shadows of their objects at an angle of forty-five degrees with the horizon, as well on the elevations as on the plans. The practice has this great convenience, namely, that the breadth of the shadow cast will then actually measure the depth of each projecting member which casts it, and the shadowed elevation may be thus made to supply a plan of the external parts of the building. Now, if in the elevation the shadows be cast at an angle of forty-five degrees, it will on a little consideration be manifest, that, being only projections of a more lengthened shadow (for those on the plan are at an angle of forty-five degrees), the actual shadow seen diagonally must be at such an angle as will make its projection equal to forty-five degrees upon the elevation; because all elevations, sections, and plans, being themselves nothing more than projections of the objects they represent, are determined by perpendicular, horizontal, or inclined parallel lines drawn from the points which bound them to the plane of projection, and similarly, a shadow in vertical projection, which forms an angle of forty-five degrees with the horizon, can only be the representation on such projection of an angle, whose measure it is our business now to determine.

2461. In the cube ABCDEFGH (*fig.* 838.) the line BD, forming an angle of forty-five degrees with the horizon, is a projection or representation of the diagonal AH on the vertical plane ABD; and our object being to find the actual angle AHB, whereof the angle ADB is the projection, we have the following method. Let each side of the cube, for example, $=10$. Then (by 907.) $AD^2+DH^2=AH^2$.

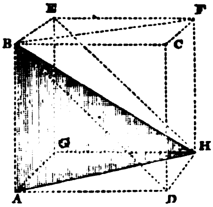

Fig. 838.

That is, $10\times10+10\times10=200=AH^2$, consequently $AH=14{\cdot}142100$.

As BAH is a right angle, we have by Trigonometry, using a table of logarithms, —

As AH (=14·14142100) or Ar. Co. Log. . 9·8494850
To tangent 45° . . . . 10·0000000
So AB (=10·00000000) log. . . 1·0000000

To tangent of angle FHB=35° 16′ . . =9·8494850
The angle ABH is therefore 54° 44′.

Hence it follows, that when shadows are projected on the plan as well as on the elevation, at an angle of forty-five degrees, the height of the sun which projects them must be 35° 16′.

2462. It is of the utmost importance to the student to recollect this fact, because it will be hereafter seen that it will give him great facility in obviating difficulty where confusion of lines may lead him astray, being, in fact, not only a check, but an assistance in proving the accuracy of his work.

2463. We now proceed to submit to the student a series of examples, containing the most common cases of shadowing, and which, once well understood, will enable him to execute any other case that may be presented to his notice.

2464. In *fig.* 839. we have on the left-hand side of the diagram the common astragal fillet and cavetto occurring in the Tuscan and other pilasters, above in elevation and below in plan. The right-hand part shows the same connected with a wall, whereon a shadow is cast by the several parts. LL is a line showing the direction of the light in projection at an angle of forty-five degrees. It will on experiment be found, by a continuation of the line, or by one parallel to it, to touch the side of the astragal at a, whence an horizontal line drawn along it will determine its line of shade. We here again repeat, to prevent misunderstanding, that in the matter we are now attempting to explain we are not dealing with reflected light, nor with the softening off of shadows apparent in convex objects, but are about to

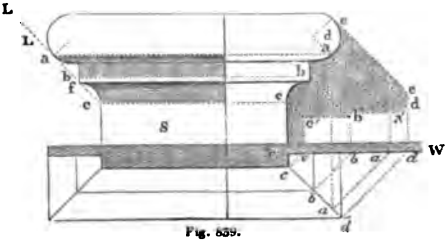

Fig. 839.

determine the mere boundaries of *shade* and *shadow* of those under consideration. The rest must be learned from observation, for the circumstances under which they are seen must constantly vary. This, however, we think, we may safely state, that if the boundaries of shade and shadow only be accurately given in a drawing (however complex), the satisfaction they will afford to the spectator will be sufficient, without further refinement. But it is not to be understood from this that we discountenance the refinement of finish in architectural subjects; all that we mean to say is, that it is not necessary. To return to the diagram: it is manifest that if the boundary of *shade* be at a from that point parallel to the direction of the light a line ab will determine the boundary of *shadow* on the fillet at b, and that from the lower edge of such fillet at f a line again parallel to the direction of the light will give at c the boundary of the shadow it casts upon the shaft S. As, in the foregoing explanation, a was the upper boundary of shade, so by producing the horizontal line which it gave to a on the right-hand side of the diagram we obtain there a corresponding point whence a line aa′ parallel to the direction of the light is to be drawn indefinitely; and on the plan a line *aa*, also parallel to the direction of the light, cutting the wall WW whereon the shadow is cast at *a*. From the point last found a vertical line from *a*, where the shadow cuts the wall on the plan, cutting aa′ in a′, will determine the point a′ in the shadow. The point e, by a line therefrom parallel to the direction of the light, will determine similarly the situation e′ by obtaining its relative seat on the diagonal *cd*, which perhaps will be at once seen by taking the extreme point d of the projection of the astragal, and therefrom drawing dd′ parallel to the direction of the light. From the line *dd*, drawn similarly parallel to the direction of the light, and cutting WW in *d*, we have the boundary of the shadow on the plan, and from that point a vertical *d*d being drawn, the boundary of shadow of the extreme projection of the astragal is thus obtained. The boundary of shadow of the fillet on the right-hand side at *b*, similarly by means of *bb*, and by the vertical *b*b′, gives the boundary point of the shadow from b. The same operation in respect of *cc* gives the boundary of shadow from c to c′ in the latter point. We have not described this process in a strictly mathematical manner, because our desire is rather to lead the student to think for himself a little in conducting it; but we cannot suppose the matter will not be perfectly understood by him even on a simple inspection of the diagram.

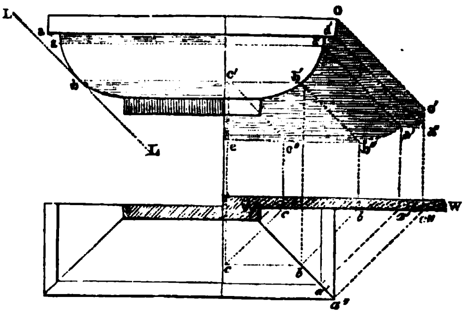

Fig. 840.

2465. In the diagram (*fig.* 840.) is represented a moulding of common occurrence in architectural subjects, and, as before, the right-hand side is the appearance of its shadow on the wall WW on the plan. It will be immediately seen that LL being the projected representation of the rays of light, the line aa determines the boundary of shadow on the ovolo, and that at b, the boundary of its shade, is also given by a line touching that point parallel to the rays, or rather projected rays, of light. On the right-hand side of the figure oo′, drawn indefinitely parallel to the direction of the light, and determined by a vertical from *a*″, the intersection by *a*″*a*″ with the wall, will give o′a″, the line of shadow of oa′. The line aa determines the shadow on the ovolo, and this continued to a′ horizontally gives also a like termination to a″ in the shadow; b, the boundary upwards of the ovolo's shade, is represented to the right by b′, and to the right on the plan by *b*, whence by a vertical cutting the line b′b″ in b″, the boundary of shadow which b′ will cast is obtained. *cc* on the plan is in projection the distance of the line of shade c′ from the wall whereon the shadow is cast, and its place in the shadow is at c″, ee″b″ being the length of horizontal shadow produced by the circumstances.

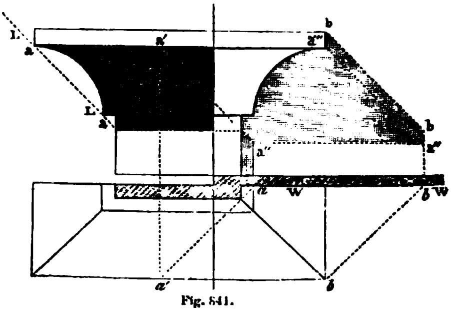

Fig. 841.

In *fig.* 841., which, it will be seen, is a common fillet and cavetto, LL is, as before, the direction of the light, and aa gives the boundary of shadow, as well of the fillet's lower edge as of the lower edge of the cavetto itself. In respect of the right-hand side of the figure, a'*a'* is a line showing in profile the extent of projection of the fillet before the wall line WW, and from a' a line drawn indefinitely parallel to the direction of the light, and terminated by the intersection of a vertical from *a'* in *a''*, will give the point a' in the shadow. So is bb found through a vertical from *b* on the wall, by a line drawn parallel to the direction of the light from *b* on the plan. The several points being connected by lines, we gain the boundaries of the shadow, wherein a'a''' is represented by a''a''.

2466. *Fig.* 842. exhibits a fillet and cyma reversa or ogee, wherein, as before, LL is the direction of the light at a similar angle to that used on the plan. From the lower edge of the fillet, parallel to the direction of the light, is obtained the point a on the ogee, and from b a similarly parallel line gives the boundary of shadow in c. A line from o in direction of the light, drawn indefinitely, intercepted by a vertical line from *d'*, its projection on the plan in *d* determines o'd, the boundary of the shadow of the fillet on the wall WW. cc''' is the line of profile of the projecting boundary in elevation, of the shade of the ogee before the wall, whereon its shadow is terminated from c and c''' by a vertical c''' c'''. bb', the boundary of shade of the ogee itself, is found in shadow by the line b'b''' drawn indefinitely parallel to the direction of the light, and terminated by a vertical from *b'*, the point on the wall correspondent to *b* on the plan, the place of the shade's point in the elevation. By the junction of the lines so found, we shall have the outline of the shades and shadows cast. It is here to be observed, that the portion of light a'b' which the moulding retains is represented in the shadow by a''b''', all the other parts of its curved form being hidden, first by the projection of the fillet, and secondly by the line of shade bb'', which acts in the same way as the fillet itself in producing the line aa', for the moment the light is intercepted, whether by a straight or curved profile, shadow must follow the shade of the moulding, whatever it be; and this is by the student to be especially observed.

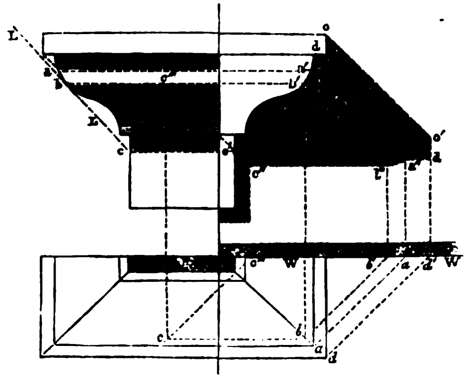

Fig. 842.

2467. *Fig.* 843. exhibits the mode of obtaining the shadows and shade in the cyma recta. LL is the direction of the light, parallel whereto the line ab determines the line of horizontal shadow cast by the lower edge of the fillet upon the cyma, and cd that of the under part of the cyma itself upon the fillet at d. cc' is the upper boundary of the shade of the cyma, and e the point for determining the shadow of the lower fillet, the points abcd corresponding with *abcd* on the plan. WW on the right hand is the face of the wall, whereto the lines *e'e''*, *d'd''*, *c'c''*, *b'b''*, and *a'a''* are drawn parallel to the direction of the light. From *e''d''c''b''a''* vertical being drawn, cutting the indefinite lines oo', a'a'', &c. parallel to the direction of the light in e'', d''', c'', b'', and a'', we have the form of the shadow in elevation. The part from b' to c' of the cyma being in light, its shadow will be the curve c'b'', wherein, if it be required on a large scale, any number of points may be taken to determine its form by means of correspondent points on the plan as for the parts already described.

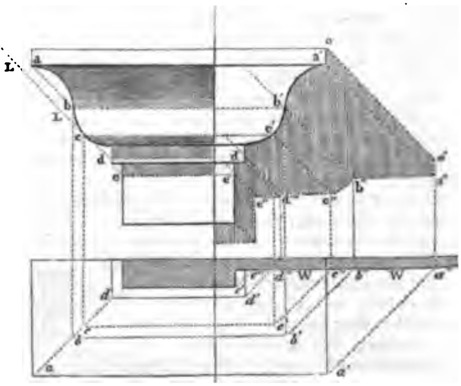

Fig. 843.

2468. *Fig.* 844. is the plan and elevation of some steps, surrounded by a wall, and P in the plan is a square pillar standing in front of them. It will be seen that the line AB corresponds with ab on the plan, as do the points E, F, G, H with efgh, from which verticals determine them in the elevation. The projection of the plinth on the lower step is found by KI and a corresponding line and vertical, which, to prevent confusion, is not shown on the plan. The shadow of the square pillar P is found in a similar manner by the line CD corresponding to cd on the plan, the shadows on the steps being also determined by the points L, M, N, O, through the medium of verticals from l, m, n, o. The left-hand side of the shadow of the pillar is determined in a similar way by the line pq, and QR in the elevation is given by qr in the plan, and is the line representing the back ps of the top of the pillar. It will be observed that we have not described any of the preceding diagrams in a strict way, neither shall we do so in those that follow, presuming that the reader has, from the perusal of the section on Descriptive Geometry acquired sufficient knowledge to follow the several lines.

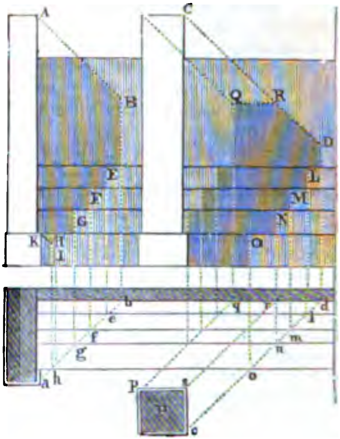

Fig. 844.

2469. The *fig.* 845. is a sort of skeleton plan and elevation of a modillion cornice, but deprived of a corona, so as to show the shadows of the modillions, independent of any connection with other parts of the assemblage. FG, HI, and AB parallel to the direction of the light determine, by means of verticals from d and i, the points of shadows from the correspondent points c, l, the points D, L, and I, whereof L is the point of shadow of M.

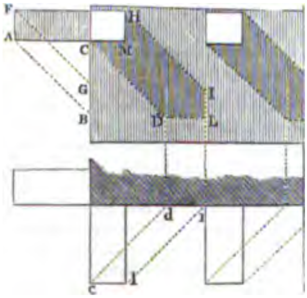

Fig. 845.

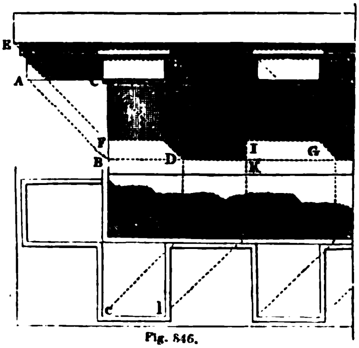

Fig. 846.

2470. In *fig.* 846. we approach a little nearer to the form of a modillion cornice. The line EF determines the shadow of the corona, and AB by means of the lines cd, Ik, and the verticals dD, kK, the boundary of the side HL of the modillions. A line also drawn horizontally from B will give the under sides of their shadows. FG is a line representing the shadow of the corona.

2471. *Fig.* 847. gives the finished modillion, and the lines Aa, Bb, Cc, Dd will determine, by horizontal lines drawn from them, the shadows which we are seeking. The auxiliary lines, to which no letters are attached, cannot fail of being understood; but if difficulty arise in comprehending them, it will be removed by planning the several points, and therefrom drawing on the plan, to meet what may be called the frieze, vertical lines to intercept those from the correspondent points in the elevation, and the operation will be facilitated, perhaps, by projecting the form of the curved lines (as seen in the figure) whereof the modillion is formed.

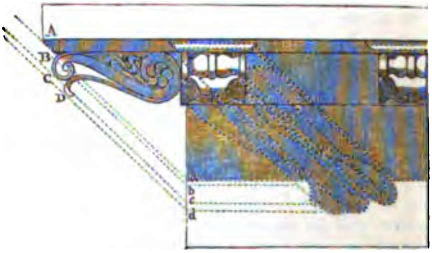

Fig. 847.

2472. *Fig.* 848. will scarcely require a description. It is a geometrical elevation of the

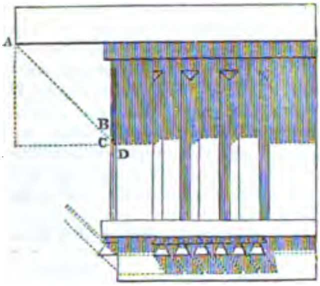

Fig. 848.

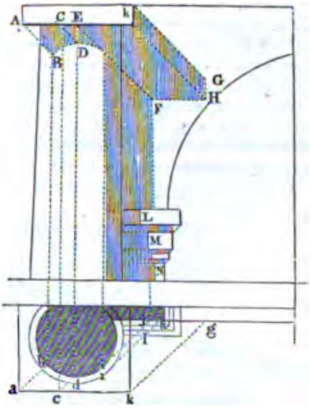

Fig. 849.

Doric triglyph and frieze, with the usual accessories. AB gives the boundary of shadow on the femora of the triglyph, AC the boundary of shadow on the light sides of the glyphs, and AD of the shadow of the corona on the frieze.

2473. *Fig.* 849. is a skeleton representation of a three-quarter column, forming part of an arcade. The abacus is the mere block of material Ak. In the plan ab shows the length of the line of shadow AB, and is determined by the vertical bB. In the same way, CD is found by cd and the vertical dD. kG is the representation of kg on the plan, and by a vertical from g the line GH is also determined; H giving also by the horizontal line FH, in which H is already found, the situation of shadow of the point E of the abacus, as also by a vertical from f. LMN are places of the shadow of the column on the impost moulding of the arch, whereof two correspondent points are seen in l and n.

2474. The form of shadow of the console in *fig.* 850. will be seen on inspection to have been found from the lines aa, cc, dd, &c. on the elevation, corresponding with *aa*, *cc*, *dd*, &c. on the section, all which are parallel to the direction of the light, and sufficiently explain themselves.

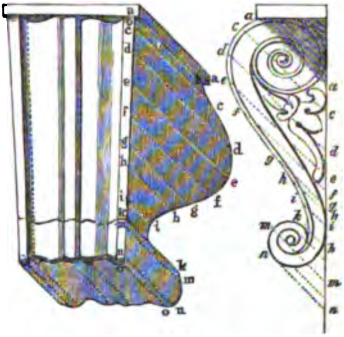

Fig. 850.

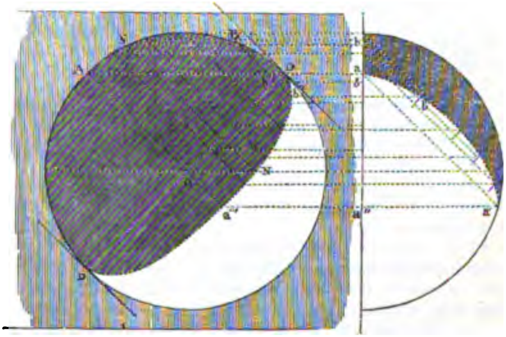

Fig. 851.

2475. *Fig.* 851. is the elevation and section of a hemispherical niche, wherein are shown the shadows cast thereon by the vertical wall in which it is placed. Through the centre O draw DD at right angles to the direction of the light, and from O draw OA parallel to the direction of the light: A will be found the point in the wall casting the longest shadow. Produce AO indefinitely; and from a, the corresponding point in the section to A on the elevation, draw aa′, which will cut the surface of the niche in a′. Draw the horizontal line a′ a″, cutting AO produced in a‴, and a″ will represent in the shadow the point A in the circumference. Take any other point B in the edge of the niche, and by means of a line drawn therefrom horizontally we have the correspondent point of B in the section. From B draw in the direction of the light the line Bb‴ b″, cutting DD on the diameter in b‴; transfer the point b‴ in the elevation to *b* in the section, and draw bb′ in the direction of the light indefinitely. Then with Bb‴ as a radius from *b* as a centre, describe an arc cutting bb′ in b′; and from b′ draw the horizontal line b′ b″, cutting Bb‴ produced in b″, and b″ will be the point in the shadow corresponding to B in the elevation. To avoid the confusion which would follow the description of the remainder of the operation, we have not encumbered the diagram with more letters of reference; the lines showing, on inspection, similar applications of the process for all parts of the curve. The fact is, that the whole of the shadow may be completed by taking the line DD as the transverse axis of an ellipsis, and finding the semi-conjugate axis Oa by the means above described, for Da″D is a semi-ellipsis in form, inasmuch as it is the projection of a section of a hemisphere. This example is applicable to the shadow of a cylindrical niche with a hemispherical head. The line NN shows the shadow of the portion of the head, and the remainder is obtained by the mere intersection of lines in the direction of the light from different points to the left of N, of which enough has been already given in the previous examples to make the application intelligible.

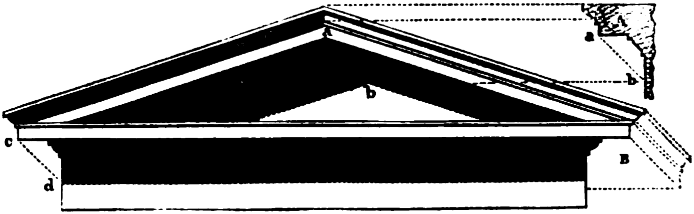

Fig. 852.

2476. *Fig.* 852. is the representation of a pediment wherein the section A is that of the mouldings of the pediment at its apex. In the section, ab drawn from the projection a of the corona in the direction of the light, determines the point b therein, wherefrom the horizontal line intercepted by the line ab in the elevation, also drawn parallel to the direction of the light, gives the point b in the elevation. A line from b, parallel to the inclined sides of the pediment on the left, will give the shadow of the corona on the tympanum on that side, and similarly the line of shadow from b on the right side. cd determines the line of shadow on the frieze, and B is the section of the shadow of the assemblage of mouldings on the right.

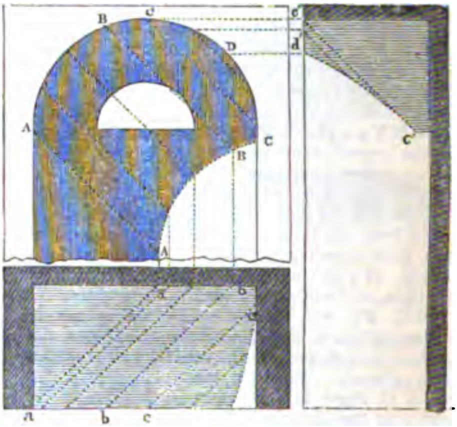

Fig. 853.

2477. In *fig.* 853. is given the plan, elevation, and section of a square recess, covered with a cylindrical head. The lines AA, BB, CC of the elevation are determined by aa, bb, and cc of the plan; and in the section c′c′ is the representation of the line cc of the plan. D, the point at which the direction of the light begins to touch the circular head, is d′ in the section.

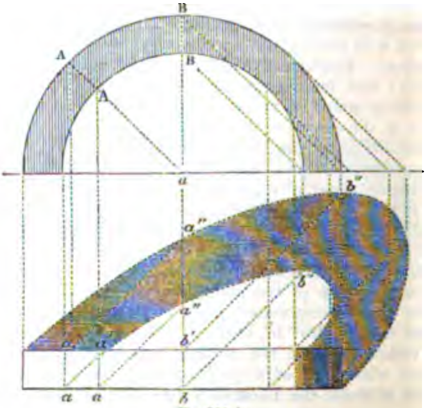

Fig. 854.

2478. *Fig.* 854. is the elevation of an arch, below which is its plan and the shadow cast by it on the plane upon which it stands. AA is shown by *aa* on the plan, the corresponding points in the rear of the arch being *a′ a′*, and *a″ a″* the points in the shadow. In a similar way, by BB corresponding with *bb′* on the plan the points *b″ b″* are obtained in the shadow.

2479. *Fig.* 855. is the plan and elevation of the upper part of a house, wherein the upper story is occupied by an attic in the centre, against which, on each flank, the sloping roof is terminated. aa on the plan in the direction of the light, produced to intersect the hip at b, gives, by a vertical to B on the elevation, the direction BB of the shadow thereon; and BB cut by AA in the direction of the light, the length BA of the line of shadow, which may, by letting fall the vertical Aa, determine the length aa on the plan. The line of shadow ac is determined by letting fall a vertical from C, where the line of shadow is intercepted by the hip of the roof; and from c the shadow will be found on trial to return as shown in the diagram. E and D on the elevation are found, as seen in previous examples, in ee, and d on the plan, and their shadows at e'e' and d'.

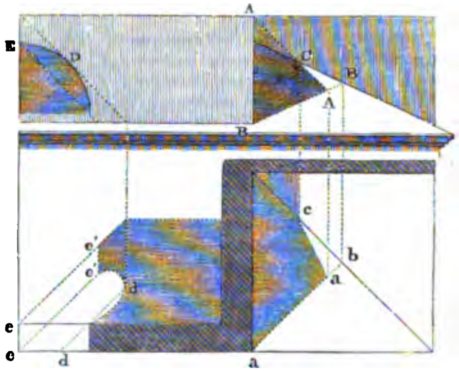

Fig. 855.

2480. What is called an attic base is given in plan and elevation by *fig.* 856. The method of obtaining the shadows thereof in plan and elevation is now to be explained. It is an example which constantly occurs in architectural subjects, and should be well studied and understood. The operations requisite for obtaining a representation of the lines of shadow of the different mouldings in this example depend upon the principles developed in the preceding subsections. The lower portion of the figure exhibits the plan, and the middle portion the elevation of the attic base in question. The uppermost portion of it presents three sections of the mouldings of the base in question cut in three different places parallel to the direction of the light. This last portion of the figure is not absolutely necessary, inasmuch as the profiles in question might have been obtained upon the elevation; but we have preferred keeping it separate to prevent a confusion of subsidiary lines. There is moreover another advantage in thus separating the parts from each other, namely, that of immediately and more distinctly seeing the lines at each selected place, in which the rays of light separate the parts actually in light from those in shadow; and where the student is likely to meet with matters of perplexity, nothing should be left untried to save his time, and, what is often more important, his patience. The mode to be adopted is as follows: —

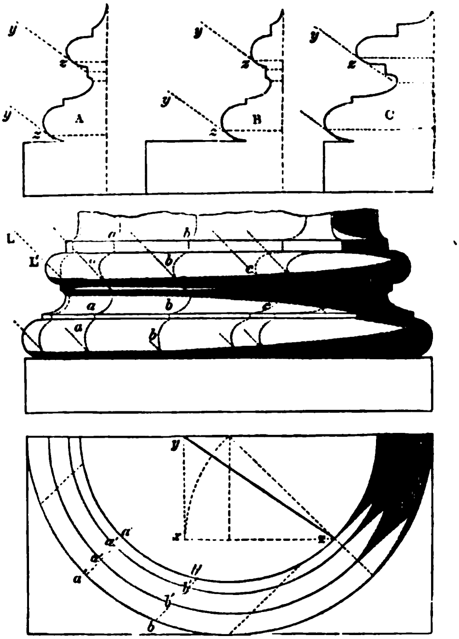

Fig. 856.

Make on the plan any number of sections *a'a'a'a'*, *b'b'b'b'* in the direction of the light, and draw on the elevation the corresponding sections *aaaa*, *bbbb*. LL being the direction of the light, draw parallel thereto tangents to the curves of the convex mouldings, and the boundaries of their shades will be obtained, as will also those of their shadows, by continuing them from such boundaries till they cut the other parts in each section, as will be more especially seen at *cc*. It will be recollected that in our first mention of the projected representation of the line of light and shadow we found that it was an angle of 54° 44' of the diagonal of a cube. This angle is set out in *xyz* on the plan. We have therefore another mode of finding the boundaries of shade and shadow on the moulding, by developing the sections *a'a'a'a'*, *b'b'b'b'*, &c., as at A, B, and C, and drawing tangents *yz* to the convex mouldings for boundaries of shade thereon, and continuing them, or otherwise, for the other parts, as shown in the diagram.

2481. In *fig.* 857., which represents the capital of a column, a similar method is used to that last mentioned for obtaining the shades and shadows, by means of *a'a'a'a'* and *b'b'b'b'*, which are shown on the elevation by *aaaa* and *bbbb*. We apprehend this will be understood by little more than inspection of it.

It is obvious that the means here adopted for obtaining the lines of shadow are precisely similar to those used in the preceding example. In this, however, the sections of the capital parallel to the direction of the light are made on the elevation, and it will be seen that many of them are not required to obtain an accurate boundary of the lines of shadow sought; for after having obtained those points from which the longest shadow falls, and on the other side those where the line of shadow commences, a curve line of an elliptical nature connects the points found. If the drawing to be made be on a large scale, it may then be worth the architect's while to increase the number of points wherefrom the shadow is to be projected, so as to produce the greatest possible accuracy in the representation.

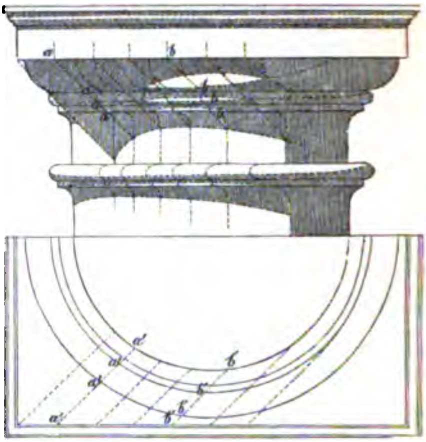

Fig. 857.

2482. The shadows of an Ionic capital are given in *fig.* 858. The shadow of the volute on the column is obtained by any number of lines AA, BB, CC, &c. from its different

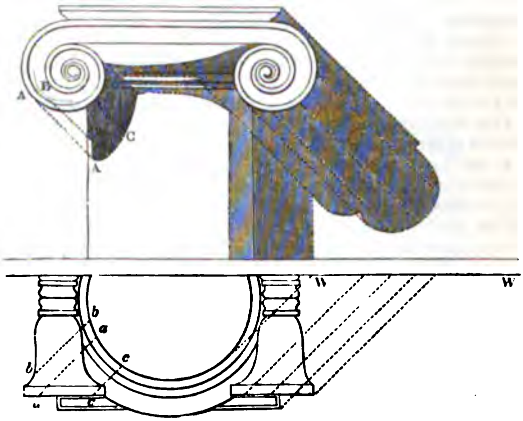

Fig. 858.

parts and verticals from their corresponding ones *aa*, *bb*, *cc*, &c. on the plan, and similarly the shadow of the capital on the wall. In this example, as in those immediately preceding, the employment of sectional lines parallel to the direction of the light is again manifest. The use of them is most especially seen in the example of the Corinthian capital which follows. As a general rule, it may be hinted to the student of sciography, that in the difficulties that may occur, they will be most expeditiously and clearly resolved by the use of the sectional lines, whereon we have thought it proper so much to dilate.

2483. The Corinthian capital in *fig.* 859. will require little more than inspection to understand the construction of its sciography; and all that we think necessary to particularise are the developed projections A, B, C, D, E, F of the abacus and the leaves, whereon the termination of the shadows at angles of 54° 44', as explained in *fig.* 856., give their respective depths on the elevation.

There is another method of arriving at the result here exhibited, by drawing sectional lines parallel to the direction of the light through the different parts and leaves of the

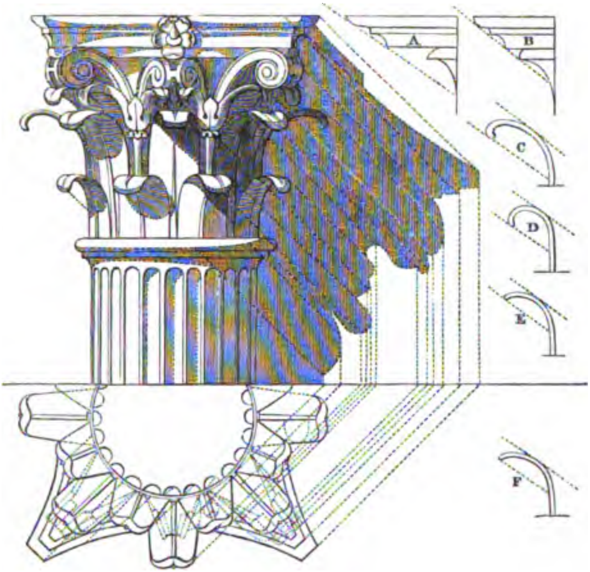

FIG. 859.

capital on its elevation, as in *fig.* 857., and such was the mode we were formerly in the habit of adopting. It however induces such a confusion of lines, that we have long since abandoned it, and have no hesitation in recommending the process here given as the best and most likely to avoid confusion. It is of course unnecessary, in making drawings, to project more than the shadow of one capital, as in a portico, or elsewhere, similar capitals, similarly exposed to the light, will project similar shadows, so that the projection on one serves for the projection on all of them.

2484. For instruction upon the mode in which reflected light acts upon objects in shade and shadow, we must refer the learner to the contemplation of similar objects in relief. The varieties of reflexes are almost infinite; and though general rules might be laid down, they would necessarily be so complicated, that they would rather puzzle than instruct, and under this head we recommend the study of nature, which will be found the best instructress the student can procure.

SECT. IV.

WORKING DRAWINGS.

2485. Working drawings are those made of the parts at large for executing the works, which could not be well done from drawings on a small scale, wherein the small parts would not be either sufficiently defined, or could not be figured so as to enable the workman to set out his work with accuracy. They are generally in outline, except the sectional parts, which are frequently hatched or shaded to bring the profiles more readily before the eye.

2486. It is obvious that though drawings made to a twelfth or a twenty-fourth part of their real size may well enough supply the wants of the workman where there is no complication in the distribution and arrangement, and in cases where there is a simple treatment of regular forms, of right angles and the like; yet in all cases wherein we have to deal with the minor details of architecture, and in construction, where the variety of forms used is infinite from the variety of the circumstances, nothing short of drawings of the full or at the least of half the size will safely guide the workman.

2487. The art of making working drawings, which must have been well understood at all periods of the practice of architecture, involves a thorough knowledge of projection, or descriptive geometry, and consists in expressing by lines all that occurs for the developement of every part of the details of a building, in plan, elevation, and profile, each part being placed for the use of the workman with clearness and precision. All the rules by which working drawings are wrought are dependent on the matter in this work already communicated to the reader, excepting only those details of the orders, and some other matters, which will be found in Book III. But we shall here, nevertheless, briefly replace before him the leading principles whereon working drawings are to be prepared. And first, he is to recollect that solids are only represented by the faces opposite to the eye; secondly, that the surfaces by which solids are enclosed are of two sorts, that is, rectilinear or curvilinear. Those bodies in which these properties are combined may be divided into three sorts: 1. Those which are bounded by plane surfaces, such as prisms, pyramids, and generally all straight work. 2. Those in which there is a mixture of straight and curved lines, as cylinders, cones, or portions of them, voussoirs of vaulting, and the like; and 3. Those solids wherein a double flexure occurs, as in the sphere, spheroid, and in many cases of voussoirs.

2488. We should, however, unnecessarily use the space allotted to us by further entering on these matters, on which enough has been already said in previous sections. The plain truth is, that working drawings are to be so made for the use of the artificer as to embody on a scale, by which no mistake ought to occur, all the information which this work has already given on construction, and that which follows in the more refined view of architecture as a fine art.

2489. In works whose magnitude is not of the first class, the drawing of every part, both in construction and in those which involve the work as one of art, every portion should be given of the full size whereof it is proposed to be executed. Where the building is large, as also the parts, this may be dispensed with; but then it becomes (the detail being drawn on a smaller but fully intelligible scale) the duty of the architect to see that the drawings he furnishes are faithfully drawn out to the full size by the artificer on proper moulds. Often it is useful, never, indeed, otherwise, to *offer up*, as it is called, small portions of mouldings on the different parts of a building, to ascertain what the effect may be likely to be at the heights fixed for their real places. In these matters he should leave no means untried to satisfy himself of the effect which what he has first planned *in small* is likely to produce when executed.

2490. We have presumed that the architect is so far educated as to have acquired a full knowledge of all that rules can teach, and that, strictly speaking, he has proportioned his work in conformity with them. Still, in real practice, there are constantly so many circumstances which concur in making it almost necessary to depart from established rules, such as surrounding buildings, where it is of importance to give predominance to a part for the purpose of making it a feature, that the expedient of trying a portion of the proposed detail in the place it is actually to occupy, is a matter that we would advise every architect to adopt after he has made and studied the working drawings whereof we treat.

2491. We have not alluded to the matters of carpentry and joinery, in which it is often necessary to give the artificer information by means of working drawings; but the methods of trussing in carpentry, and of framing in joinery, often require working drawings. What has already been exhibited under those heads (2031, *et seq.*) will prevent his being left uninstructed, and will, moreover, have afforded such information as to prepare him, by the exercise of his own ingenuity, for such cases as may not have been specially given in the examples herein contained. We therefore here close our observations under this section by an intimation to the student, that the proper preparation of working drawings for the use of the artificer tests his acquaintance with the theory and practice of the art, and is of the utmost importance to the pocket of the employer from whom he receives a commission, whereof it is his duty as a gentleman never to lose sight.

BOOK III.

PRACTICE OF ARCHITECTURE.

CHAP. I.

THE PRINCIPAL PARTS OF A BUILDING.

SECT. I.

BEAUTY IN ARCHITECTURE.

2492. THE existence of architecture as a fine art is dependent on *expression*, or the faculty of representing, by means of lines, words, or other media, the inventions which the architect conceives suitable to the end proposed. That *end* is twofold; to be useful, and to connect the use with a pleasurable sensation in the spectator of the invention. In eloquence and poetry the end is to instruct, and such is the object of the higher and historical classes of painting; but architecture, though the elder of the arts, cannot claim the rank due to painting and poetry, albeit its end is so much more useful and necessary to mankind. In the sciences the end is utility and instruction, but in them the latter is not of that high moral importance, however useful, which allows them for a moment to come into competition with the great arts of painting, poetry, and eloquence. It will be seen that we here make no allusion to the lower branches of portrait and landscape painting, but to that great moral and religious end which fired the mind of Michael Angelo in the Sistine Chapel, and of Raffaelle Sanzio in the Stanze of the Vatican and in the Cartoons. Above the lower branches of painting just mentioned, the art whereof we treat occupies an exalted station. In it though the chief end is to produce an useful result, yet the expression on which it depends, in common with the other great arts, brings each within the scope of those laws which govern generally the fine arts whose object is beauty. Beauty, whatever difference of opinion may exist on the means necessary to produce it, is by all admitted to be the result of every perfection whereof an object is susceptible, such perfections being altogether dependent on the agreeable proportions subsistent between the several parts, and those between the several parts and the whole. The power or faculty of inventing is called *genius*. By it the mind is capable of conceiving and of expressing its conceptions. *Taste*, which is capable of being acquired, is the natural sensation of a mind refined by art. It guides genius in discerning, embracing, and producing beauty. Here we may for a moment pause to inquire what may be considered a standard of taste, and that cannot be better done than in the words used on the subject by Hume (Essay xxiii.): "The great variety of tastes," says that author, "as well as of opinion, which prevails in the world, is too obvious not to have fallen under every one's observation. Men of the most confined knowledge are able to remark a difference of taste in the narrow circle of their acquaintance, even where the persons have been educated under the same government and have early imbibed the same prejudices. But those who can enlarge their view to contemplate distant nations and remote ages are still more surprised at the great inconsistence and contrariety. We are apt to call *barbarous* whatever departs widely from our own taste and apprehension, but soon find the epithet of reproach retorted on us, and the highest arrogance and self-conceit is at last startled on observing an equal assurance on all sides, and scruples, amidst such a contest of sentiment, to pronounce positively in its own favour." True as are the observations of this philosopher in respect of a standard of taste, we shall nevertheless attempt to guide the reader to some notion of a standard of taste in architecture.

2493. There has lately grown into use in the arts a silly pedantic term under the name of Æsthetics, founded on the Greek word 'Αισθητικὸς, one which means having the power of perception by means of the senses; said to be the science whereby the first principles in all the arts are derived, from the effect which certain combinations have on the mind as connected with nature and reason: it is, however, one of the metaphysical and useless additions to nomenclature in the arts, in which the German writers abound, and in its application to architecture of least value; because in that art form is from construction so limited by necessity, that sentiment can scarcely be said to be further connected with the art than is necessary for keeping the subordinate parts of the same character as the greater ones under which they are combined; and, further, for thereby avoiding incongruities.

2494. It is well known that all art in relation to nature is subject to those laws by which nature herself is governed, and if we were certain that those rules of art which resulted from reason were necessarily and actually connected with sensation, there would be no difficulty in framing a code of laws whereon the principles of any art might be firmly founded. "Principles in art," as well defined by Payne Knight, "are no other than the trains of ideas which arise in the mind of the artist out of a just and adequate consideration of all those local, temporary, or accidental circumstances upon which their propriety or impropriety, their congruity or incongruity, wholly depend." By way of illustrating the observation just made, we will merely allude to that maxim in architecture which inculcates the propriety of placing openings over openings and piers over piers, disallowing, in other words, the placing a pier over an opening without the exhibition of such preparation below as shall satisfy the mind that security has been consulted. There can be no doubt that a departure from the maxim creates an unpleasant sensation in the mind, which would seem to be immediately and intimately connected with the laws of reason; but there is great difficulty in satisfying one's self of the precise manner in which this operates on the mind, without a recurrence to the primitive types in architecture, and thence pursuing the inquiry. But in the other arts the types are found in nature herself, and hence in them no difficulty occurs in the establishment of laws, because we have that same nature whereto reference may be made. We shall have to return to this subject in the section on the Orders of Architecture, to which we must refer the reader, instead of pursuing the subject here.

2495. Throughout nature beauty seems to follow the adoption of forms suitable to the expression of the end. In the human form there is no part, considered in respect to the end for which it was formed by the great Creator, that in the eye of the artist, or rather, in this case the better judge, the anatomist, is not admirably calculated for the function it has to discharge; and without the accurate representation of those parts in discharge of their several functions, no artist by means of mere expression, in the ordinary meaning of that word, can hope for celebrity. This arises from an inadequate representation having the appearance of incompetency to discharge the given functions; or, in other words, they appear unfit to answer the end.

2496. We are thus led to the consideration of *fitness*, which, after all, will be found to be the basis of all *proportion*, if not proportion itself. Alison, in his *Essay on Taste*, says, "I apprehend that the beauty of proportion in forms is to be ascribed to this cause," (fitness) "and that certain proportions affect us with the emotion of beauty, not from any original capacity in such qualities to excite this emotion, but from their being expressive to us of the fitness of the parts to the end designed." Hogarth, who well understood the subject, concurs with Alison in considering that the emotion of pleasure which proportion affords does not resemble the pleasure of sensation, but rather that feeling of satisfaction arising from means properly adapted to their end. In his *Analysis of Beauty* that great painter places the question in its best and truest light, when, speaking of chairs and tables, or other common objects of furniture, he considers them merely as fitted from their proportions to the end they have to serve. In the same manner, says Alison, "the effect of disproportion seems to me to bear no resemblance to that immediate painful sensation which we feel from any disagreeable sound or smell, but to resemble that kind of dissatisfaction which we feel when means are unfitted to their end. Thus the disproportion of a chair or table does not affect us with a simple sensation of pain, but with a very observable emotion of dissatisfaction or discontent, from the unsuitableness of their construction for the purposes the objects are intended to serve. Of the truth of this every man must judge from his own experience." We cannot refrain from continuing our extracts from this most intelligent author. "The habit," he says, "which we have in a great many familiar cases of immediately conceiving this fitness from the mere appearance of the form, leads us to imagine, as it is expressed in common language, that we determine proportion by the eye, and this quality of fitness is so immediately expressed by the material form, that we are sensible of little difference between such judgments and a mere determination of sense; yet every man must have observed that in those cases where either the object is not familiar to us or the construction intricate our judgment is by no means speedy, and that we never discover the proportion until we previously discover the principle of the machine or the means by which the end is produced."

2497. The nature of the terms in which we converse shows the dependence of proportion on fitness, for it is the sign of the quality. The natural answer of a person asked why the proportion of any building or machine pleased him, would be, because the object by such proportion was fit or proper for its end. Indeed, proportion is but a synonyme of fitness, for if the form be well contrived, and the several parts be properly adjusted to their end, we immediately express our opinion that it is well proportioned.

2498. There is, however, between proportion and fitness, a distinction drawn by our author, which must be noticed. "Fitness expresses the relation of the whole of the means to the end; proportion, the proper relation of a part or parts to their end." But the distinction is too refined to be of importance in our consideration; for the due proportion of parts is simply that particular form and dimension which from experience has been found best suited to the object in view. "Proportion," therefore continues Alison, "is to be considered as applicable only to forms composed of parts, and to express the relation of propriety between any part or parts and the end they are destined to serve."

2499. Forms are susceptible of many divisions, and consequently proportions; but these are only subordinate to the great end of the whole. Thus, for instance, in the constantly varying forms of fashion, say in a chair or table, the merely ornamental parts may bear no relation to the general fitness of the form, but they must be so contrived as to avoid unpleasant sensation, and not to interfere with the general fitness. If we do not understand the nature of its fitness, we cannot judge of the proportion properly. "No man," says Alison, "ever presumes to speak of the proportions of a machine of the use of which he is ignorant." When, however, we become acquainted with the use or purpose of a particular class of forms, we at the same time acquire a knowledge which brings under our view and acquaintance a larger circle of agreeable proportions than the rest of the world understand; and those parts which by others are regarded with indifference, we contemplate with pleasure, from our superior knowledge of their fitness for the end designed. The proportions of an object must not in strength be carried beyond what is required for fitness, for in that case they will degenerate into clumsiness, whilst elegance, on the contrary, is the result of the nicest adjustment of proportion.

2500. Fitness cannot exist in any architectural object without *equilibrium* in all the parts as well as the whole. The most complete and perfect notion that can be conceived of *stability*, which is the result of equilibrium, may be derived from the contemplation of an horizontal straight line; whilst, on the contrary, of instability nothing seems more expressive than a vertical straight line. These being, then, assumed as the extremes of stability and instability, by carrying out the gradations between the two extremes, we may, extending in two parts the vertical line, obtain various forms, more or less expressive of stability as they approach or recede from the horizontal line. In *fig.* 860. we have, standing on the same base, the general form of the lofty Gothic spire; the pleasing, solid, and enduring form of the Egyptian pyramid; and that of the flat Grecian pediment: which last, though in its inclination adjusted on different grounds, which have been examined in Book II. Chap. III. subsect. 2027, *et seq.*, is an eminent instance of stability. The spire, from its height and small base, seems to possess but a tottering equilibrium compared with the others.

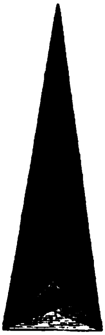

Fig. 860.

2501. Stability is obviously dependent on the laws of gravitation, on which, under the division of statics, not only the architect, but the painter and sculptor, should bestow considerable attention. We cannot for a moment suppose it will be disputed that at least one of the causes of the beauty of the pyramid is a satisfactory impression on the mind of the state of rest or stability it possesses. Rest, repose, stability, balance, all meaning nearly the same thing, are then the very essential ingredients in fitness; and therefore, in architectural subjects, instability, or the appearance of it, is fatal to beauty. Illustrations of this exist in the famous Asinelli and Garisendi towers at Bologna, and at Pisa in the celebrated leaning Campanile.

2502. It may be objected to what we have written, that fitness alone will not account for the pleasure which arises in the contemplation of what are called the orders of architecture, and Alison seems very much to doubt whether there be not some other cause of beauty. It will, however, be our business to show how the ancients, their inventors, considered principally their fitness; and upon these grounds to show, moreover, how the proportions in ancient examples varied, and may be still further varied, without infringing upon the principles which guided them in the original invention. Payne Knight has well observed, "that the fundamental error of imitators in all the arts is, that they servilely copy the effects which they see produced, instead of supplying and adopting the principles which guided the original artists in producing them; wherefore they disregard all those local, temporary, or accidental circumstances upon which their propriety or impropriety, their congruity or incongruity, wholly depend." "Grecian temples, Gothic abbeys, and feudal castles were all well adapted to their respective uses, circumstances, and situations; the distribution of the parts subservient to the purposes of the whole; and the ornaments and decorations suited to the character of the parts, and to the manners, habits, and employments of the persons who were to occupy them: but the house of an English nobleman of the 18th or 19th century is neither a Grecian temple, a Gothic abbey, nor a feudal castle; and if the style of distribution or decoration of either be employed in it, such changes and modifications should be admitted as may adapt it to existing circumstances, otherwise the scale of its exactitude becomes that of its incongruity, and the deviation from principle proportioned to the fidelity of imitation." This is but another application of the principle of fitness which we have above considered, the chief foundation of beauty in the art. We have shown how it is dependent on stability as a main source of fitness, and here subjoin some maxims which will lead the student to fitness in his designs, and prevent him from running astray, if he but bring himself to the belief that they are reasonable, and founded upon incontestable grounds, which we can assure him they are.

First. Let that which is the stronger part always bear the weaker.

Second. Let solidity be always real, and not brought to appear so by artifice.

Third. Let nothing be introduced into a composition whose presence is not justified by necessity.

Fourth. Let unity and variety be so used as not to destroy each other.

Fifth. Let nothing be introduced that is not subordinate to the whole.

Sixth. Let symmetry and regularity so reign as to combine with order and solidity.

Seventh. Let the proportions be of the simplest sort.

Eighth. Let him recollect that nothing is beautiful which has not some good and useful end.

If, after having made his design, he will scrupulously test it by these maxims *seriatim*, and will strike out what is discordant with the tenor of them, he will have overcome a few of the difficulties which attend the commencement of his career.

2503. We are not of the same opinion with those who, on a geometrical elevation of a building, draw lines from its apex, which, bounding the principal parts of the outline, find a pyramidal form, and thence infer beauty of general outline. If those who favour such a notion will but reflect for a moment, they must see that this cannot be a test of its effect, inasmuch as the construction of a geometrical elevation of any edifice supposes it to be viewed at an infinite distance, whereas, in fact, it is most generally viewed under angles which would puzzle the most learned architect, without full investigation, to discover the primary lines which they assume to be the causes of its beauty. The obscurations and foreshortenings that take place are at points of view near the building itself; and, however judicious it may be to form the general masses in obedience to such a system, so as to produce an effect in the distance that may be in accordance with the principle, it would be extremely dangerous to lay the principle down as a law. The finest view of St. Paul's is perhaps a little east of Fetter Lane, on the northern side of Fleet Street; but it would puzzle any one to discover its pyramidal form from that point of view.

2504. The beauty of the proportions of architecture in the interiors of buildings is dependent on those which govern the exteriors. Much has been said on proportions of rooms, which, hereafter, we shall have to notice: we mean the proportions of their length to their breadth and height. That these are important, we cannot deny; but whether the beauty of a room is altogether dependent on the due adjustment of these, we have some doubts; that is, under certain limits. We here address ourselves more particularly to that fitness which, in ornamenting a ceiling, for example, requires that the beams which appear below the general surface should invariably fall over piers, and that in this respect corresponding sides should be uniform. In the study of this point, Inigo Jones is the great English master who has left the student the most valuable examples of this branch of the art.

2505. It may, perhaps, be useful to observe generally that the bare proportions of the interiors of apartments depend on the purposes for which they are intended, and according to these we seek immediately for the expression of their fitness. This point, therefore, involves on the part of the architect so general an acquaintance with the most refined habits of his employers, that we should be almost inclined to agree with Vitruvius on the multifarious qualifications necessary to constitute a good one. Certain it is that no instructions he can receive for building a mansion will qualify him without a great acquaintance with the habits of the upper classes of society.

2506. We have already stated that it is hopeless to arrive at a fixed standard of taste. That considered worthy of the appellation will not be so considered in another. "The sable Africans," says Knight, quoting from Mungo Park, "view with pity and contempt the marked deformity of the Europeans, whose mouths are compressed, their noses pinched, their cheeks shrunk, their hair rendered lank and flimsy, their bodies lengthened and emaciated, and their skins unnaturally bleached by shade and seclusion, and the baneful influence of a humid climate." In the countries of Europe, where some similarity of taste may be expected, the tyranny of fashion, no less than that of habit and circumstance, has, and always will have, its influence on the arts. Within the short space of even a few months we have seen what is called the *renaissance* style of architecture imported from France, drawing into its vortex all classes of persons, many of them among the higher ranks, possessed of education to have patronised better taste; and in architecture, and some other arts, no one solves the question of what is really right by saying that there have been errors in the tastes of different ages.

2507. The specimens of Greek sculpture, whose beauty is founded in nature herself, will throughout all time excite the admiration of the world; because in this case, the standard or type being nature, mankind generally may be supposed to be competent judges of the productions of the art. But it is very different in architecture, whose types in every style are, as respects their origin, uncertain; and when we are asked whether there be a real and permanent principle of beauty in the art, though we must immediately reply in the affirmative, we are at the same time constrained to refer it to the quality of fitness. If this were not the case, how could we extend our admiration to the various styles of Egyptian, Grecian, Roman, Gothic, and Italian architecture? These at first appear, compared with each other, so dissimilar, that it seems impossible to assign beauty to one without denying it to the rest. But on examination each will be found so fitted to its end, that such cause alone will be found to be the principal source of the pleasure that an educated mind receives from each style; and that thence it arises, rather than from any certain or definable combinations of forms, lines, or colours that are in themselves gratifying to the mind or agreeable to the organs of sensation. If this be true, what becomes of the doctrine of the German æsthetical school, so vaunted of by self-constituted critics and reviewers, who pass their judgment *ex cathedrâ* on works they have never seen, and, strange to say, are tolerated for a moment by the public? The truth is, the public rarely give themselves the trouble to judge; and unless led, which is easily done by the few, do not undertake the trouble of judging for themselves. That the Egyptian pyramid, the Grecian and the Roman temple, the early Christian basilica, the Gothic cathedral, the Florentine palace, the Saracenic mosque, the pagoda of the East, are all beautiful objects, we apprehend none will dispute; but there is in none of them a common form or standard by which we can judge of their beauty: the only standard on which we can fall back is the great fitness of them, under their several circumstances, for the end proposed in their erection.

2508. We are thus unavoidably driven to the conclusion that beauty in its application to architecture changes the meaning of the word with every change of its application; for those forms which in one style are strictly beautiful on account of their fitness, applied to another become disgusting and absurd. By way of illustrating this, let us only picture to ourselves a frieze of Grecian triglyphs separating the nave and clerestory of a Gothic cathedral. From what we have been taught to consider the type of the Doric frieze connected with its triglyphs an idea of fitness immediately arises in the mind; but we cannot trace its fitness in a dissimilar situation, neither can we comment on such an incongruity better than in the oft-quoted lines of Horace: —

" Humano capiti cervicem pictor equinam
Jungere si velit, et varias inducere plumas
Undique collatis membris, ut turpiter atrum
Desinet in piscem mulier formosa supernè;
Spectatum admissi risum teneatis amici?"

The influence of circumstances in every age has imparted to each style of architecture its peculiar beauty and interest; and until some extraordinary convulsion in society give the impetus to a new one, we are constrained to follow systems which deprive us of other novelty than those of changes which are within the spirit of the universally established laws of the art. Turn to the Gothic churches of the present day, — the little pets of the church commissioners and clergy. What objects of ineffable contempt the best of them are! The fact is, the religious circumstances of the country have so changed that they are wholly unsuitable in style to the Protestant worship. Had, with the scanty means afforded to the architects, such a model as St. Paul's, Covent Garden, been adopted, we might have seen a number of edifices in the country, though

" Facies non omnibus una
Nec diversa tamen,"

that might have been an honour to the age in which we live, and suitable to the circumstances of the times.

2509. Unity and harmony in a work necessarily enter into that which is beautiful; and it will not therefore require any argument to show that from a mixture of styles in any building incongruity and unfitness, and consequently a want of unity and harmony, must be the result. Hence we cannot agree with those wise reviewers who advocate the possibility of amalgamating the arch with the severe Grecian style. We leave them to their dreams, and trust that before we give them credence we may have some proof of their practical power in this respect.

2510. Symmetry is that quality which, as its name imports, from one part of an assemblage of parts enables us to arrive at a knowledge of the whole. It is a subordinate, but nevertheless a necessary, ingredient in beauty. It is necessary that parts performing the same office in a building should be strictly similar, or they would not *ex vi termini* be symmetrical; so, when relations are strictly established between certain parts, making one the measure of another, a disregard of the symmetry thus induced cannot fail of destroying beauty. But here again we have to say, that for want of attention to the similarity of the parts, or neglect of the established relations on which the whole is founded, they have lost their symmetry, and have thus become *unfit* for their purpose; so that thus again we return to fitness as the main foundation of beauty.

2511. Colour abstractedly considered has little to do with architectural beauty, which is founded, as is sculpture, on fine form. We are here speaking generally, and are not inclined to assert that the colour of a building in a landscape is unimportant to the general effect of that landscape, or that the colours used on the walls of the interior of a building are unessential considerations; but we do not hesitate to say that they are of minor consequence in relation to our art. We believe it would be difficult to paint (we mean not in the sense of the artist) the interior of the banqueting room at Whitehall, were it restored to its original destination, and divested of the ruinous accessories which from its original purpose have turned it from a banqueting room into a chapel,—we believe, we say, that it would be difficult to paint it so as to destroy its internal beauty. But as we intend to be short under this head, we shall quote a brochure touching on this subject published by us in 1837.

2512. One of the beauties tending to give effect to the edifices of Greece has been, on the testimony of almost all travellers, the colour of the materials whereof they are composed. Dr. Clarke observes that a warm ochreous tint is diffused over all the buildings of the Acropolis, which *he* says is peculiar to the ruins of Athens. "Perhaps," says the author, "to this warm colour, so remarkably characterising the remains of ancient buildings at Athens, Plutarch alluded" (*In Vita Periclis*) "in that beautiful passage cited by Chandler, where he affirmed *that the structures of Pericles possessed a peculiar and unparalleled excellence of character; a certain freshness bloomed upon them and preserved their faces uninjured, as if they possessed a never-fading spirit, and had a soul insensible to age.*" It is singular that recent discoveries have incontestably proved that this species of beauty at all events did not originally exist in them, inasmuch as it is now clearly ascertained that it was the practice of the Greeks to paint the whole of the inside and outside of their temples in party colours. It had been some time known that they were in the habit of painting and picking out the ornaments on particular parts of their buildings; but M. Schaubert, the architect of the King of Greece, found on examination that this fell far short of the extent to which this species of painting was carried, and M. Semper, another German architect, has fully corroborated the fact in his examination of the Temple of Theseus. The practice was doubtless imported into Greece from Egypt, and was not to be easily abandoned, seeing the difficulty of falling away from the habits of a people whence it seems certain the arts of Greece more immediately came. It is by no means uncommon for a person to be fully alive to all the beauties of form, without at the same time having a due feeling or perception of the beauty resulting from harmony in colouring. It is therefore not to be assumed that the Greeks, though given to a practice which we would now discourage, possessed not that taste in other respects which has worthily received the admiration of posterity. The practice of painting the inside and outside of buildings has received the name of *polychromatic* architecture, and we shall here leave it to the consideration of the student as a curious and interesting circumstance, but certainly without a belief that it could add a charm to the stupendous simplicity and beauty of such a building as the Parthenon.

2513. After all that we have said of fitness, it will be expected that in *decoration* it shall form a principal ingredient. By the term decoration we understand the combination of objects and ornaments that the necessity of variety introduces under various forms, to embellish, to enrich, and to explain the subjects whereon they are employed. The art of decoration, so as to add to the beauty of an object, is, in other words, that of carrying out the emotions already produced by the general form and parts of the object itself. By its means the several relations of the whole and the parts to each other are increased by new combinations; new images are presented to the mind whose effect is variety, one great source of pleasure. From these observations two general rules may be deduced in respect of decoration. *First*, that it must actually be or seem to be necessary. *Second*, that such objects must be employed in it as have relation to the end of the general object of the design. We are not to suppose that all parts of a work are susceptible of ornament. Taste must be our guide in ascertaining where decoration is wanted, as well as the quantity requisite. The absence of it altogether is in many cases a mode of decoration. As in language its richness and the luxuriance of images do not suit all subjects, and simplicity in such cases is the best dress, so in the arts of design many subjects would be rather impoverished than enriched by decoration. We must therefore take into consideration the character of the building to be decorated, and then only apply such ornament as is necessary and suitable to that character. We may judge of its necessity if the absence of it causes a dissatisfaction from the void space left; of its suitableness, by its developing the character. History has recorded the contempt with which that decorator was treated who ornamented the senate house with statues of wrestlers, and the gymnasium with statues of senators.

2514. By some the art of architecture itself has been considered nothing more than that of decorating the buildings which protection from the elements induces us to raise.

2515. The objects which architecture admits for decoration result from the desire of producing *variety*, *analogy*, and *allegory*. We here follow Quatremère de Quincy. (*Encyc. Method.*) The first seems more general than the others, as being common among all nations that practise building. It is from this source we have such a multitude of cut-work, embroidery, details, compartments, and colours, more or less minute, which are found in every species of architecture. It would be useless for the most philosophical mind to seek for the origin of these objects in any want arising out of the mere construction, or in any political or superstitious custom. Systems of conjecture might be exhausted without arriving one point nearer the truth. Even in the most systematic of the different kinds of architecture, namely, that of the Greeks, we cannot avoid perceiving a great number of forms and details whose origin is derived from the love of variety, and that alone. In a certain point of view, thus considered, an edifice is nothing more than a piece of furniture, a vase, an utensil, the ornaments on which are placed more for the purpose of pleasing the eye than any other. Such, for instance, are the roses of caissons in ceilings and sofites, the leaves round the bell of the Corinthian capital, the Ionic volutes, and many others, besides universally the carving of mouldings themselves. These ornaments, drawn from the storehouse of nature, are on that account in themselves beautiful; but it is their transference to architecture, which in the nature of things can have but a problematical and conjectural origin, that seems to indicate a desire to vary the surface. Unless it was the desire of variety that induced them, we know not what could have done so.

2516. It has been well observed by the author we have just quoted, that though the art has been obliged to acknowledge that many of its decorations depend in their application on such forms as necessity imposes, and in the formation of them on chance, caprice, or whatever the love of variety may dictate, yet in the disposition of them there must reign an order and arrangement subordinate to that caprice, and that at this point commences the difference between architecture as an art subservient to laws which are merely dependent on the pleasure imparted to the eye, and those which depend on the mere mechanical disposition of the building considered as a piece of furniture. Architecture, of all the arts, is that which produces the fewest emotions of the minds of the many, because it is the least comprehensible in regard to the causes of its beauty. Its images act indirectly on our senses, and the impressions it seems to make appear reducible chiefly to magnitude, harmony, and variety, which after all are not qualities out of the reach of an architect of the most ordinary mind, and therefore not — at least the first and last — unattainable where economy does not interfere to prevent the result to be attained.

2517. Analogy, the second of the objects by which decoration is admitted into architecture, seems to be resultant from the limited nature of all human inventions in the arts, and the power of being unable to invent except by imitation and alteration of the forms of objects pre-existent. It is most difficult to discard altogether what have been considered types in architecture, and that difficulty has so prevailed as to limit those types to their most probable origin in the case of the orders.

2518. The reader will begin to perceive that our analogy in decoration tends upon trees for columns, the ends of beams for triglyphs, and the like. Whatever truth there may be in this analogy, it is now so established as to guide the rules of decoration that are involved in it; and it must be conceded, that if we are desirous of imitating the peculiar art of any country, we have no hope of success but by following the forms which the construction in such country engenders; and we must admit that, as far as external circumstances can direct us, the architecture of Greece, which, modified, has become that of the whole of Europe, and will become that of America, seems so founded on the nature of things, that, however we may doubt, it would not be prudent to lead the reader away from the consideration, and perhaps from a belief, that such is the truth. Without holding ourselves bound by the analogy of the types of the tree and the cross beam, which appear to have guided the architects of Greece, we can without hesitation assert, that whenever those have been abandoned the art has fallen on the most flagrant vices; witness the horrors of the school of Borromini, where the beams are broken, pediments, which are the gables of roofs, are broken into fantastic forms, and none of the parts seem naturally connected with each other. The works of the school in question seem indeed so broken up, that the study of them would almost convince an impartial and competent judge that the converse of its practice is sufficiently beautiful to establish the truth of the types whereon we have here and before expressed our scepticism. "Sitôt," says De Quincy, "que le génie decorateur s'est cru libre des entraves de l'analogie, toutes les formes caractéristiques se sont contournées, perverteés, et dénaturées, au point qu'il y a entr'elles et celle de la bonne architecture, plus de distance qu'entre celles-ci et les types de la primitive construction."

2519. In the decoration of architecture, neither of the other two means employed are more important than that ocular language which architecture occasionally employs in its ornaments. By its use architecture is almost converted into painting, and an edifice becomes a picture, or a collection of pictures, through the aid of the sculptor. We shall refer to no other building than the Parthenon to prove the assertion. Here the history of the goddess is embodied in the forms of the building, and to the decoration thus introduced the subordinate parts of the sculpture, if it be not heresy so to call them, is kept so under that we are almost inclined to cry out against their not having been principals instead of accessories. This is the true principle upon which buildings should be decorated to impress the mind of the spectator with the notion of beauty, and the principle which, carried out, no matter what the style be, will insure the architect his most ample reward, reputation. The matter that is supplied by allegory for decoration in architecture may be considered under three heads — *attributes*, *figures*, and *paintings*.

2520. The first takes in all those foliages, plants, flowers, and fruits, which from their constant use in sacrifices were at last transferred from the altar to the walls of the temple. The garlands, festoons, chaplets, and crowns which we find sculptured on temples seem to have had their origin from the religious ceremonies performed in them; as do the instruments of sacrifice, vases, the heads of the victims, pateræ, and all the other objects employed in the worship of the ancients. Thus, in architecture, these have become conventional signs, indicating the destination of the buildings to which they are applied. From the particular application of some ornaments on temples we derive in the end a language in the arts of imitation. It was thus that the eagle grasping in his talons the attribute of Jupiter, came to represent eternity and omnipotence; the myrtle and dove of Venus, the passion of love; the lyre and laurel of Apollo, to point to harmony and glory; the spear and helmet of Mars, to represent war. Palms and crowns became the emblems of victory, as did the olive the emblem of peace. In the same way the ears of corn of Ceres, the serpent of Esculapius, the bird of Minerva, and the cock of Mercury were equivalent to the expression of abundance, science, and vigilance. Instruments of the arts, sciences, in short, all objects useful to the end for which an edifice is erected, naturally become signs of that edifice; but applied otherwise become absurd. What, for instance, could be more ridiculous than placing ox sculls and festoons on the frieze of a Protestant church? — and yet this has been done in our own days.

2521. Figures of men and animals come under the second head. The application of these may be seen to their highest perfection in the Parthenon, to which we have already alluded. They may be introduced in low, high, or full relief. In the last case their situation is usually that of a niche. We shall say no more on the subject of figures than that of course they must have relation to the end for which the edifice is erected, and if not in that respect perfectly intelligible are worse than useless.

2522. The walls of Pompeii furnish ancient examples of the decoration obtained by the aid of painting, as do the loggie of the Vatican and the ceilings of the Farnesina modern examples of it. Herein the moderns have far surpassed anything we know of the ancient application of painting. Sculpture, however, seems more naturally allied to architecture than painting, and, except in purely decorative painting on walls and ceilings, the introduction of it seems bounded within narrow limits. The rules as to fitness of the subjects introduced, applicable to the first two heads, are equally so under that of painting.

Sect. II.

THE ORDERS.

2523. An order in architecture is a certain assemblage of parts subject to uniform established proportions, regulated by the office that each part has to perform. It may be compared to what organisation is in animal nature. As from the paw of a lion his dimensions may be deduced, so from a triglyph may be found the other parts of an example of the Doric order, and from given parts in other orders the whole configuration may be found. As the genus may be defined as consisting of *essential* and *subservient* parts, the first-named are the column and its entablature, which, as its name imports, is as it were the tabled work standing on the column. The subservient parts are the mouldings and detail into which the essential parts are subdivided, and which we shall hereafter separately consider. The species of orders are five in number, Tuscan, Doric, Ionic, Corinthian, and Composite, each of whose mass and ornaments are suited to its character and the expression it is intended to possess. These are the five orders of architecture, in the proper understanding and application whereof is laid the foundation of architecture as an art. The characters of strength, grace, and elegance, of lightness and of richness, are distinguishing features of the several orders, in which those characters ought to be found not only in the column employed, but should pervade the whole composition, whereof the column is, as it were, the regulator. The mode of setting up, or, as it is technically termed, profiling an order, will be given in a subsequent part of this section. Here we shall merely observe that the entablature is subdivided into an architrave, which lies immediately upon the column, a frieze lying on the architrave, and a cornice, which is its uppermost subdivision. The height of these subdivisions together, that is, the whole height of the entablature, is one fourth that of the column according to the practice of the ancients, who in all sorts of entablatures seldom varied from that measure either in excess or defect. "Palladio, Scamozzi, Alberti, Barbaro, Cataneo, Delorme, and others," says Sir William Chambers, "of the modern architects, have made their entablatures much lower in the Ionic, Composite, and Corinthian orders than in the Tuscan or Doric. This, on some occasions, may not only be excusable but highly proper; particularly where the intercolumniations are wide, as in a second or third order, in private houses, or inside decorations, where lightness should be preferred to dignity, and where expense, with every impediment to the conveniency of the fabric, are carefully to be avoided; but to set entirely aside a proportion which seems to have had the general approbation of the ancient artists is surely presuming too far."

2524. As rules in the fine arts which have obtained almost universal adoption are founded on nature or on reason, we may be pretty certain that they are not altogether empirical, albeit their origin may not be immediately apparent. The grounds on which such rules are founded will, however, in most cases become known by tracing them to first principles, which we shall here endeavour to do in respect of this very important relation of height between the column and its entablature. We were first led into this investigation by the perusal of a work by M. Lebrun, entitled *Théorie de l'Architecture Grecque et Romaine deduite de l'analyse des Monumens antiques*, fol. Paris, 1807; but our results differ very widely from those of Lebrun, as will be seen on reference to that work.

2525. One of the most obvious principles of proportion in respect of loads and supports, and one seemingly founded on nature herself, is, that a support should not be loaded with a greater mass or load than itself; or, in other words, that there should be an equality between weights and supports, or, in the case in point, between the columns and entablature. In respect of the proportion of the voids below the entablature between the columns or supports, a great diversity of practice seems to have prevailed, inasmuch as we find them varying from 1·08 to 2·18, unity being the measure of the supports. Lebrun makes the areas of the supports, weights, and voids equal to one another, and in what may be termed the monumental examples of the Doric order, such as the Parthenon, &c., he seems borne out in the law he endeavours to establish; but in lighter examples, such as the temple (Ionic) of Bacchus at Teos, where the supports are to the voids as 1 : 2·05, and in the temple of Minerva Polias, where the ratio is as 1 : 2·18, he is beyond all question incorrect: indeed there hardly seems a necessity for the limitation of the voids he prescribes, seeing that, without relation separately to the weight and support, stability would be obtained so long as the centre of gravity of the load fell within the external face of the support. If it be admitted that, as in the two examples above mentioned, the voids should be equal to the supports jointly, we have a key to the rule, and instead of being surprised at the apparently strange law of making the entablature one fourth of the height of the column, we shall find that no other than the result assumed can flow from the investigation.

2526. In fig. 861. let AB be the height of the column, and let the distance between the columns be one third of the height of the column = CD. Now if AB be subdivided into four equal parts at *a*, *b*, and *c*, and the horizontal lines *ad*, *be*, and *cf* be drawn; also, if CD be divided horizontally into four equal parts, and lines be drawn perpendicularly upwards intersecting the former ones, the void will be divided into sixteen equal parallelograms, one half whereof are to be the measure of the two whole supports BC and DE; and DE being then made equal to one half of CD, it will be manifest, from inspection, that the two semi-supports will jointly be equal to eight of the parallelograms above mentioned, or one half of the void. We have now to place the entablature or weight AGHI upon the supports or columns, and equal to them in mass. Set up from A to F another row of parallelograms, each equal to those above mentioned, shown on the figure by AFKI. These will not be equal to the supports by two whole parallelograms, being in number only six instead of eight; dividing, therefore, 8, the number in the supports, by 6, the number already obtained, we have 1·333, &c., which is the height to be assigned to AG, so that the weight may exactly equal the supports, thus exceeding one quarter of the height of the support (or column) by $\frac{333}{1000}$ of such quarter, a coincidence sufficient to corroborate the reason on which the law is founded.

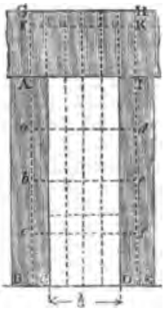

Fig. 861.

2527. From an inspection of the *figs.* 861, 862, 863. it appears that when the void is one third the height of the supports in width, the supports will be 6 diameters in height; when one fourth of their height, they will be 8 diameters high; also that the intercolumniation, called systylos or of two diameters, is constant by the arrangement.

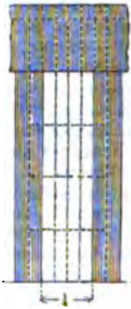

Fig. 862.

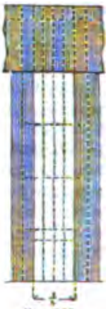

Fig. 863.

2528. Trying the principle in another manner, let *fig.* 864. be the general form of a tetrastyle temple wherein the columns are assumed at pleasure 8 diameters in height. Then 4 × 8 = 32 the areas of the supports; and as to fulfil the conditions the three voids are equal to twice that area, or 64, they must consequently be in the aggregate equal to 8 diameters, for $\frac{64}{8} = 8$, and the whole extent will therefore be equal to 12 diameters of a support or column. To obtain the height of the entablature so that its mass may equal that of the supports, as the measures are in diameters, we have only to divide 32, the columns, by 12, the whole extent of the façade, and we obtain two diameters and two thirds of a diameter for the height of the entablature, making it a little more than one quarter of the height of the column, and again nearly agreeing in terms of the diameter with many of the finest examples of antiquity. If a pediment be added, it is evident, the dotted lines AC, CB being bisected in *a* and *b* respectively, that the triangles AE*a*, *b*FB are respectively equal to CD*a* and D*b*C, and the loading or weight will not be changed.

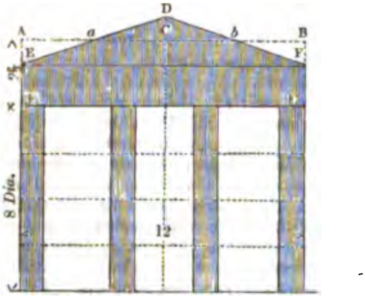

Fig. 864.

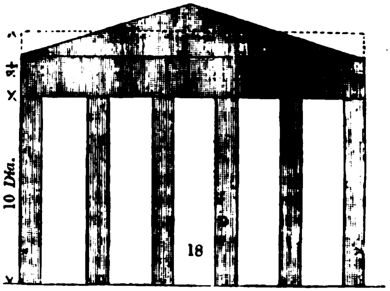

Fig. 865.

2529. Similar results will be observed in fig. 865., where the height is 10 diameters: the number of columns 6, the whole therefore 180, the supports being 60. Here $\frac{60}{18} = 3\frac{1}{3}$ diameters will be the height of the entablature. This view of the law is further borne out by an analysis of the rules laid down by Vitruvius, book iii. chap. 2.; — rules which did not emanate from that author, but were the result of the practice of the time wherein he lived, and, within small fractions, strongly corroborative of the soundness of the hypothesis of the voids being equal to twice the supports. Speaking of the five species of temples, after specifying the different intercolumniations, and recommending the eustylos as the most beautiful, he thus directs the formation of temples with that interval between the columns. "The rule for designing them is as follows: — The extent of the front being given, it is, if tetrastylos, to be divided into 11½ parts, not including the projections of the base and plinth at each end; if hexastylos, into 18 parts; if octastylos, into 24½ parts. One of either of these parts, according to the case, whether tetrastylos, hexastylos, or octastylos, will be a measure equal to the diameter of one of the columns." . . . . "The heights of the columns will be 8½ parts. Thus the intercolumniations and the heights of the columns will have proper proportions." In the same chapter he gives directions for setting out aræostyle, diastyle, and systyle temples, which directions it is not here necessary to investigate, and our limits do not indeed permit us so to do. We will therefore now examine the directions quoted. The tetrastylos is 11½ parts wide and 8½ high; the area therefore of the whole front becomes 11½ × 8½ = 97¾. The four columns are 4 × 8½ = 34, or a very little more than one third of the whole area. The remaining two thirds, speaking in round numbers, being given to the intercolumns or voids.

2530. The hexastylos (see *fig.* 865.) is 18 parts long and 8½ high; the whole area therefore is 18 × 8½ = 153. The six columns will be 6 × 8½ = 51, or exactly one third of the whole area; the voids or intercolumns occupying the remaining two thirds.

2531. The octastylos is 24½ parts in extent and 8½ in height. Then 24½ × 8½ = 208¼.

The eight columns will be $8 \times 8\frac{1}{2} = 68$, being a trifle less than one third of the area, and the voids or intercolumns about double, or the remaining two thirds.

The average of the intercolumns in the first case will be $\frac{11\frac{1}{2}-4}{3} = 2\frac{1}{2}$ diameters.

In the second case - - - - - $\frac{18-6}{5} = 2\frac{2}{5}$ diameters.

In the third case - - - - - $\frac{24\frac{1}{2}-8}{7} = 2\frac{357}{1000}$ diameters.

A discrepance between practice and theory, unless extremely wide, must not be allowed to interfere with principles, and we have therefore no hesitation in candidly submitting a synoptical view of some of the most celebrated examples of antiquity in which a comparison is exhibited between the voids and supports; certain it is that in every case the former exceed the latter, and that in the earlier examples of Doric, the ratio between them nearly approached equality. In comparing, however, the supports with the weights, there is every appearance of that part of the theory being strictly true, for in taking a mean of the six examples of the Doric order, the supports are to the weights as 1 : 1·16; in the five of the Ionic order as 1 : 1·05; and in the four of the Corinthian order as 1 : 1·04: a coincidence so remarkable, that it must be attributed to something more than accident, and deserves much more extended consideration than it has hitherto received.

Building.	Order.	Number of Columns.	Supports.	Weights.	Voids.
Temple of Jupiter Nemeus - -	Doric	6	1·00	0·79	1·03
Parthenon - - - - - -	—	8	1·00	1·07	1·04
Temple at Bassæ - - - -	—	6	1·00	1·14	1·16
Temple of Minerva at Sunium -	—	6	1·00	1·40	1·17
Temple of Theseus at Athens -	—	6	1·00	1·13	1·21
Temple of Jupiter Panhellenius -	—	6	1·00	1·45	1·36
Temple of Erectheus - - -	Ionic	6	1·00	0·89	1·24
Temple of Fortuna Virilis at Rome	—	4	1·00	1·15	1·71
Temple on the Ilyssus - - -	—	4	1·00	0·96	1·72
Temple of Bacchus at Teos - -	—	8	1·00	1·35	2·05
Temple of Minerva Polias, Athens -	—	4	1·00	1·01	2·18
Portico of Septimius Severus - -	Corinthian.	6	1·00	0·93	1·37
Maison Carrée at Nismes - -	—	6	1·00	0·98	1·58
Temple at Jackly - - -	—	6	1·00	0·90	1·62
Pantheon, Rome - - - -	—	8	1·00	1·43	1·84

There is a curious fact connected with the hypothesis which has been suggested that requires notice; it is relative to the area of the points of support for the edifice which the arrangement affords. In *fig.* 866. the hatched squares represent the plans of quarter piers of columns in a series of intercolumniations every way, such intercolumniations being of two diameters, or four semidiameters. These, added to the quarter piers, make six semidiaters, whose square 36 is therefore the area to be covered with the weight. The four quarter piers or columns = 4, hence the points of support are $\frac{1}{9}$ of the area $= 0·111$. Now in the list (1583.) of the principal buildings in Europe the mean ratio is 0·168 differing only 0·057 from the result here given; but if we select the following buildings, the mean will be found to differ much less.

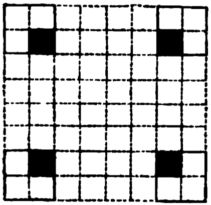

Fig. 866.

Temple of Peace -	0·127
S. Paolo fuori le Murà	0·118
S. Sabino - - -	0·100
S. Filippo Neri - -	0·129 Sum = 0·474. Mean $\frac{0·474}{4} = 0·118$.

MOULDINGS.

2532. The subservient parts of an order, called mouldings, and common to all the orders, are eight in number. They are — 1. The *ovolo*, *echinus*, or *quarter round*. (*Fig.* 867.) It is formed by a quadrant, or sometimes more of a circle, but in Grecian examples its section is obtained by portions of an ellipse or some other conic section. This latter observation is

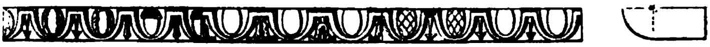

Fig. 867.

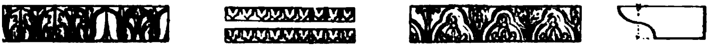

Fig. 868.

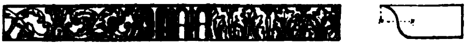

Fig. 869.

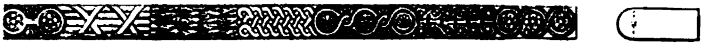

Fig. 870.

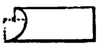

Fig. 871.

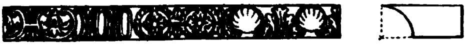

Fig. 872.

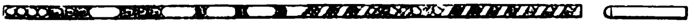

Fig. 873.

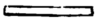

Fig. 874.

applicable to all mouldings of Greek examples, and we shall not repeat it in enumerating the rest of them. It is commonly found under the abacus of capitals. The ovolo is also almost always placed between the corona and dentils in the Corinthian cornice: its form gives it the appearance of seeming fitted to support another member. It should be used only in situations above the level of the eye. 2. The *talon*, *ogee*, or *reversed cyma* (*fig.* 868.) seems also, like the ovolo, a moulding fit for the support of another. 3. The *cyma*, *cyma recta*, or *cymatium* (*fig.* 869.) seems well contrived for a covering and to shelter other members. The cyma recta is only used properly for crowning members, though in Palladio's Doric, and in other examples, it is found occasionally in the bed mouldings under the corona. 4. The *torus* (*fig.* 870.), like the astragal presently to be mentioned, is shaped like a rope, and seems intended to bind and strengthen the parts to which it is applied; while, 5. The *scotia* or *trochilos* (*fig.* 871.), placed between the fillets which always accompany the tori, is usually below the eye; its use being to separate the tori, and to contrast and strengthen the effect of other mouldings as well as to impart variety to the profile of the base. 6. The *cavetto*, *mouth*, or *hollow* (*fig.* 872.) is chiefly used as a crowning moulding, like the cyma recta. In bases and capitals it is never used. By workmen it is frequently called a *casement*. 7. The *astragal* (*fig.* 873.) is nothing more than a small torus, and, like it, seems applied for the purpose of binding and strengthening. The astragal is also known by the names of *bead* and *baguette*. 8. The *fillet*, *listel*, or *annulet* (*fig.* 874.) is used at all heights and in all situations. Its chief office is the separation of curved mouldings from one another.

2533. Sir William Chambers observes on these different mouldings that their inventors meant to express something by their different figures, and that the destinations above mentioned "may be deduced not only from their figures, but from the practice of the ancients in their most esteemed works; for if we examine the Pantheon, the three columns in the Campo Vaccino, the temple of Jupiter Tonans, the fragments of the frontispiece of Nero, the basilica of Antoninus, the forum of Nerva, the arches of Titus and Septimius Severus, the theatre of Marcellus, and indeed almost every ancient building, either at Rome or in other parts of Italy and France, it will be found that in all their profiles the cyma and cavetto are constantly used as finishings, and never applied where strength is required. That the ovolo and talon are always employed as supporters to the essential members of the composition, such as the modillions, dentils, and corona; that the chief use of the torus and astragal is to fortify the tops and bottoms of columns, and sometimes of pedestals;" . . . "and that the scotia is employed only to separate the members of bases, for which purpose the fillet is likewise used not only in bases but in all kinds of profiles." It is the fitness of these forms for their ends in their several situations that gives them a positive and natural beauty, which is immediately destroyed by their change of position, as primary forms of architecture; and the author just quoted well observes, "that Palladio erred in employing the cavetto under the corona in three of his orders, and in making such frequent use through all his profiles of the cyma as a supporting member. Nor has Vignola been more judicious in finishing his Tuscan cornice with an ovolo; a moulding extremely improper for the purpose, and productive of a very disagreeable effect; for it gives a mutilated air to the whole profile, so much the more striking, as it resembles exactly that half of the Ionic cornice which is under the corona."

2534. The simplest method of describing the contours of mouldings is to form them of quadrants of circles. Those of the ovolo, talon, cyma, and cavetto being equal to their height, and those of the curve parts of the torus, and astragal equal to half their height. Circumstances, however, often justify a variation from the rule; and if that be the case, the ovolo, talon, cyma, and cavetto may be either described from the summits of equilateral triangles, or be composed of portions of the ellipsis, which latter was almost constantly used by the Greeks. By means of it also the scotia may be produced, as well as by quadrants of circles; but the curved part of the torus and astragal is always semicircular in form, and if more projection is wanted it is obtained by the use of straight lines.

ORNAMENTS OF MOULDINGS.

2535. In ornamenting the profile of an order, repose requires that some mouldings should be left plain. If all were enriched, confusion instead of variety would result. Except for particular purposes, the square members are rarely carved. There are but few examples in the best age of the art in which the corona is cut; indeed at this moment the only one that occurs to us wherein work is in fine style is that of the three columns in the Campo Vaccino. So where the ovolo above and talon below it are carved, the dentil band between them should be uncut. Scamozzi, in the third chapter of his sixth book, inculcates that ornaments should be neither profuse nor abundant, neither are they to be too sparingly introduced. Thus they will be approved if applied with judgment and discretion. Above all things, they are to be of the most beautiful forms and of the exactest proportions; ornaments in buildings, being like the jewels used for the decoration of princes and princesses and persons of high rank, must be placed only in proper situations. Neither must variety in ornaments be carried to excess. We have to recollect that, being only accessories, they must not obtrude upon but be kept subordinate to the main object. Thus ornaments applied to mouldings should be simple, uniform, and combining not more than two distinct forms in the same enrichment; and when two forms are used on the same moulding they should be cut equally deep, so that an uninterrupted appearance may be preserved. Mouldings of the same form and size on one and the same profile should be similar; and it is moreover a requisite of the greatest importance, so to distribute the centres of the ornaments employed that the centre of one may fall exactly over the centres of those below, of which the columns of the Campo Vaccino form an example for imitation in this respect. Nothing is more offensive than, for example, to see the middle of an egg placed over the edge of a dentil, and in another part of the same moulding to see them come right, centre over centre, and the like negligent and careless distribution. This may always be avoided by making the larger parts regulate the smaller. Thus where there are modillions they must be made to govern the smaller ornaments above and below them, and these smaller ones should always be subdivided with a view to centring with the larger parts. The larger parts are dependent on the axes of the columns and their intercolumniations; but all these must be considered in profiling the order. It will of course be necessary to give the ornaments such forms as may be consistent with the character of the order they enrich. The enrichment of a frieze depends upon the destination of the building, and the ornaments may have relation to the rank, quality, and achievements of the proprietor. We do not agree with Chambers in condemning the introduction of arms, crests, and cyphers, as an unbecoming vanity in the master of the fabric. These may often be so introduced as to indicate the alliances of the family, and thus give a succinct history of its connections. In Gothic architecture we know the practice induced great beauty and variety. We have before observed, in Sect. I. of this Book (2520.), that the instruments and symbols of pagan worship are highly indecorous, not to say ludicrous, on edifices devoted to the Christian religion.

2536. In carving ornaments they must be cut into the solid, and not carved as if they were applied on the solid, because the latter practice alters their figure and proportion. In fact, every moulding should be first cut with its contour plain, and then carved, the most prominent part of the ornament being the actual surface of the moulding before carving, observing that all external and re-entering angles are kept plain, or have only simple leaves with the central filament expressed on or in the angle. In the circular temple of Tivoli the principle of cutting the ornament out of the solid is carried out so far, that the leaves, as usual in most examples of the Corinthian order, instead of being mere appliquées to the bell of the capital, are actually cut out of it.

2537. The degree of relief which ornaments ought to have is dependent on their distance from the eye and the character of the composition: these matters will also regulate the degree of finish they ought to possess. There are some mouldings whose profile is indicative of bearing weight, as the ovolo and talon, which by being deeply cut, though themselves heavy in character, are thereby susceptible of having great lightness imparted to them, whilst such as the cyma and cavetto should not be ornamented deep in the solid. The imitation from nature of the objects represented should be carefully observed, the result whereof will impart beauty and interest to the work on which such attention is bestowed.

CHARACTERS OF THE ORDERS.

2538. In the First Book of this work, Sect. XI. (133, *et seq*) we have considered the history of the five orders of architecture; we shall here offer some general observations upon them before proceeding to the detail of each separately. The orders and their several characters and qualities do not merely appear in the five species of columns into which they have been subdivided, but are distributed throughout the edifices to which they are applied, the column itself being the regulator of the whole composition. It is on this account the name of orders has been applied to the differently formed and ornamented supports, as columns, which have received the names of the Doric, Ionic, Corinthian, Tuscan, and Composite orders, whereof the three first are of Grecian origin, and the two last, it is supposed, of Italian or Roman origin. Each of these, by the nature of its proportions, and the character resulting from them, produces a leading quality, to which its dimensions, form, and ornaments correspond. But neither of the orders is so limited as to be confined within the expression of any single quality. Thus the strength indicated in the Doric order is capable of being modified into many shades and degrees of that quality. We may satisfy ourselves of this in an instant by reference to the early compared with the later Doric column of the Greeks. Thus the columns of the temple at Corinth are only four diameters high, while those of the portico of Philip are six and a half.

2539. As the Doric seems the expression of strength, simplicity, and their various modes, so the Ionic, by the rise in height of its shaft and by the slenderness of its mass, as well as by the elegance of its capital, indicates a quality intermediate between the grave solidity of the Doric and the elegant delicacy of the Corinthian. Bounded on one side by strength, and by elegance on the other, in the two orders just named, the excess of elegance in the Corinthian order ends in luxury and richness, whereof the character is imprinted on it.

2540. We cannot here refrain from giving, in the words of the excellent Sir Henry Wotton, a quaint and homely, but most admirable description of these five orders, from his *Elements of Architecture*. " First, the *Tuscan* is a plain massive rural pillar, resembling some sturdy, well-limbed labourer, homely clad, in which kind of comparisons, Vitruvius himself seemeth to take pleasure." (Lib. iv. cap. 1.) . . . " The *Dorique order* is the gravest that hath been received into civil use, preserving, in comparison of those that follow, a more *masculine aspect* and little trimmer than the *Tuscan* that went before, save a sober garnishment now and then of *lions' heads* in the *cornice*, and of *triglyphs* and *metopes* always in the *frize*." . . . " To discern him will be a piece rather of good *heraldry* then of *architecture*, for he is knowne by his place when he is in company, and by the peculiar ornament of his *frize*, before mentioned, when he is alone." . . . " The *Ionique order* doth represent a kind of feminine slendernesse; yet, saith Vitruvius, not like a light housewife, but, in a decent dressing, hath much of the *matrone*." . . . " Best known by his trimmings, for the bodie of this *columne* is perpetually *chaneled*, like a thick-pleighted gowne. The *capitall* dressed on each side, not much unlike women's wires, in a spiral wreathing, which they call the *Ionian voluta*." . . . " The *Corinthian* is a columne lasciviously decked like a courtezan, and therefore in much participating (as all inventions do) of the place where they were first born, *Corinth* having beene, without controversie, one of the wantonest towns in the world." . . . " In short, as plainness did characterise the *Tuscan*, so, much delicacie and varietie the *Corinthian* pillar, besides the height of his rank." . . . " The last is the *compounded order*, his *name* being a briefe of his *nature* : for this pillar is nothing in effect but a *medlie*, or an *amasse* of all the precedent *ornaments*, making a new kinde by stealth, and though the most richly tricked, yet the poorest in this, that he is a borrower of his beautie." Each of the orders, says De Quincy, is, then, in the building to which it is applied, the governing principle of the forms, taste, and character of that system of moral order met with in Grecian architecture which alone seems to have suited the physical order of proportions with each part, so that what is agreeable, ornate, and rich is equally found in the whole as in the parts.

2541. On the two Latin orders we do not think it necessary to say more than that they will be fully described in following pages. The invention of new orders must arise out of other expressions of those qualities which are already sufficiently well and beautifully expressed; hence we consider, with De Quincy, to attempt such a thing would be vain. Chambers thus expresses himself on this subject, without the philosophy of De Quincy, yet with the feelings of a learned and experienced architect : " The ingenuity of man has, hitherto, not been able to produce a sixth order, though large premiums have been offered, and numerous attempts been made, by men of first-rate talents to accomplish it. Such is the fettered human imagination, such the scanty store of its ideas, that Doric, Ionic, and Corinthian have ever floated uppermost, and all that has ever been produced amounts to nothing more than different arrangements and combinations of their parts, with some trifling deviations, scarcely deserving notice; the whole tending generally more to diminish than to increase the beauty of the ancient orders." Again : " The suppression of parts of the ancient orders, with a view to produce novelty, has of late years been practised among us with full as little success; and though it is not wished to restrain sallies of imagination, nor to discourage genius from attempting to invent, yet it is apprehended that attempts to alter the primary forms invented by the ancients, and established by the concurring approbation of many ages, must ever be attended with dangerous consequences, must always be difficult, and seldom, if ever, successful. It is like coining words, which, whatever may be their value, are at first but ill received, and must have the sanction of time to secure them a current reception."

2542. In the progress of the five orders, from the Tuscan up to the Composite, taking seven diameters for the height of the Tuscan column, and eleven for that of the Composite, if the entablature be taken of the same absolute height in all, and at the same time in height one quarter of that of the column, we shall have the height of the entablature in terms of the diameter of the column, as follows: —

In the Tuscan order . $\frac{1}{4}$ of $\frac{7}{1}$ = $1\frac{3}{4}$ entablature diameters high.
In the Doric order . $\frac{1}{4}$ of $\frac{8}{1}$ = 2 entablature diameters high.
In the Ionic order . $\frac{1}{4}$ of $\frac{9}{1}$ = $2\frac{1}{4}$ entablature diameters high.
In the Corinthian order $\frac{1}{4}$ of $\frac{10}{1}$ = $2\frac{1}{2}$ entablature diameters high.
In the Composite order $\frac{1}{4}$ of $\frac{11}{1}$ = $2\frac{3}{4}$ entablature diameters high.

HEIGHT AND DIMINUTION OF COLUMNS.

2543. Vitruvius tells us that the ancients were accustomed to assign to the Tuscan column seven of its diameters for the height; to the Doric, eight; to the Ionic, nine; and to the Corinthian and Composite, ten. Scamozzi, the leader of the moderns, adopts similar proportions. But these are not to be considered as more than an approximation to the limits, nor as relating to the proportions between the heights and diameters of the ancient Doric examples, whereof in our First Book we have examined certain specimens. This work cannot be extended to a representation of the variety under which the orders have appeared in their various examples of each order. The works in which they are contained must be consulted for particulars of detail in this respect. Our intention is to give general information on the subject, and to follow, with few exceptions, in that respect, the precepts of Vignola, as tending to the most generally pleasing results, and as being also those which have been adopted on the Continent for general instruction in the art.

2544. We have already spoken (2524, *et seq.*) of the general proportion of the height of the entablature to that of the column as one fourth, and, without returning to the discussion of the propriety of that proportion, will only here incidentally mention that Scamozzi, Barbaro, Alberti, and Palladio have not assigned so great a height to their entablatures, chiefly, it appears, because they seemed to consider the slenderness of the columns in the more delicate orders unsuited to the reception of heavy burdens. If, however, the reader will bear in recollection what has been said at the beginning of this section relative to the supports and weights, it will directly occur to him that the practice these great masters sanctioned is not founded upon just deductions. Chambers seems to have had a glimpse of this theory, but without any notion of its developement, when he says, "It must be remembered that, though the height of an entablature in a delicate order is made the same as in a massive one, yet it will not, either in reality or in appearance, be equally heavy, for the quantity of matter in the Corinthian cornice A (*fig.* 875.) is considerably less than in the Tuscan cornice B, and the increased number of parts composing the former of these will of course make it appear far lighter than the latter." He was, however, nearer the exact truth where he speaks in a previous passage of the possibility of increasing the intervals between the columns.

2545. The diminution or tapering form given to a column, whereof all the authors find the type, whether truly or not, in that of the trunk of a tree, in the ancient examples, sometimes commences from the foot of the shaft, sometimes from a quarter or one third of its height, in which case the lower part is a perfect cylinder. Though the latter method has been mostly adopted by modern artists, the former seems more to have prevailed among the ancients. Of the method of entasis, that is, of swelling columns as they rise, we have already spoken in the First Book (144.). A curve of diminution, if we may so term it, in which the lower part does not much vary from the cylinder, but never much exceeding its boundary for the height of one third upwards, is the best, and to something like that we now come. Blondel (*Resolution des quatre principaux Problemes d'Architecture*) says, that the best and simplest instrument for the diminution of columns is that invented by Nicomedes for describing the first conchoid, which, applied at the bottom of the shaft, gives, by continued motion, both the swelling and the diminution. Vignola had not strictly anticipated Blondel in this method, which, it is said, was that used for the columns in the Pantheon; but the old master had come so near to it that we shall first describe Vignola's method, and then that proposed by Blondel. Vignola having already spoken of the common practice, says,

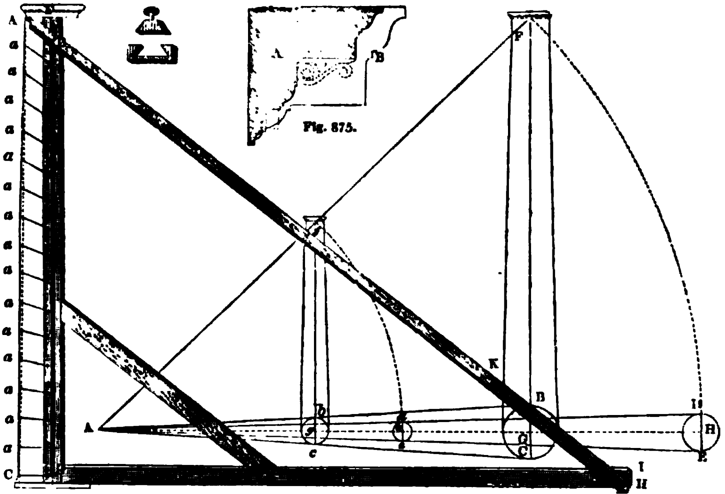

Fig. 875.

Fig. 876.

(Stampani's edit. *Dei cinque Ordini d'Architettura*, Roma, 1770, cap. 7. p. 51.), "In respect of this second mode, it is my own discovery, and will be soon understood by the figure, though not so well known as the first named. The measures of the column having been fixed, namely, the height of the shaft and its upper and lower diameters, from C (*fig.* 876.), draw an indefinite line through D perpendicular to the axis of the column. From A, the extreme point of the upper semi-diameter, to B, a point in the axis, set off CD the lower semidiameter. Through B from A draw the line ABE, cutting the indefinite line CD in E, and from the point of intersection E and through the axis of the column draw any number of rays, as EB*a*, whereon, from the axis towards the circumference, setting off the interval CD, any number of points *aaa* may be found, and through them a curve being drawn gives the swell and diminution of the shaft.

2546. This method is so far defective as to require the curve to be drawn by hand on the application of a flexible ruler through the points found. To remedy the defect, Blondel, who on investigation of the curve found it to be a conchoid, applied the instrument of Nicomedes for the purpose, the description of which instrument here follows. The height of the shaft and the upper and lower diameters of the column having been determined, as also the length (*fig.* 876.) of the line CDE, take three rulers, FG, ID, and AH, of which let FG and ID be fastened together at right angles in G. From top to bottom let a dovetail groove be cut down the middle of FG, and at E on the ruler ID, whose length from the centre of the groove in FG is the same as that of the point of intersection from the axis of the column, fix a pin. On the ruler AH set off the distance AB equal to the lower semidiameter of the column CD, and at the other end of the ruler cut a slit through it from H to K, the length whereof must at least be equal to the difference in length between EB and ED, and its breadth sufficient to admit the pin fixed at E to pass through the slit, and allow the ruler to slide thereon. Now, the middle of the groove in the ruler FG being placed exactly over the axis of the column, the ruler AH in moving along the groove will with its extremity A describe the curve A*aa*C, which curve is the same as that produced by Vignola's method, except that the operation is performed by the continued motion of the ruler AH. If the rulers be of an indefinite size, and the pins at E and B be made to move along their respective rulers, so as to be able to increase or diminish at pleasure the lengths AB and DE, the instrument will answer for drawing columns of any size.

2547. The diminution of the column as respects quantity is rarely in ancient examples less than one eighth of the lower diameter of the column, nor often more than one sixth, as will be seen in the subjoined examples. One sixth is the diminution recommended by Vitruvius, and followed by Vignola, in all his orders, except the Tuscan. In the following table the first column contains the order; the second, the example; the third, the height of the column in English feet and decimal parts of a foot; the fourth column shows its diameter in similar terms; and the fifth the ratio of diminution. The dimensions are from Perrault, reduced here from French to English feet.

Order.	Examples.	Height of Column in English Feet.	Diameter of Column in English Feet.	Ratio of Diminution.
Doric	Theatre of Marcellus	22·386	3·198	0·200
—	Coliseum	24·384	2·865	0·077
Ionic	Temple of Concord	38·376	4·485	0·182
—	Temple of Fortuna Virilis	24·340	3·109	0·125
—	Coliseum	24·518	2·909	0·166
Corinthian	Temple of Peace	52·400	6·041	0·111
—	Portico of Pantheon	38·998	4·796	0·106
—	Altars of Pantheon	11·548	1·465	0·133
—	Temple of Vesta	29·226	3·109	0·111
—	Temple of the Sybil at Tivoli	20·254	2·487	0·133
—	Temple of Faustina	38·376	4·796	0·133
—	Columns of Campo Vaccino	39·975	4·840	0·111
—	Basilica of Antoninus	39·442	4·752	0·106
—	Arch of Constantine	23·097	3·435	0·117
—	Interior of Pantheon	29·314	3·642	0·133
—	Portico of Septimius	39·442	3·632	0·125
Composite.	Baths of Diocletian	37·310	3·553	0·200
—	Temple of Bacchus	11·371	1·443	0·111
—	Arch of Titus	17·056	2·102	0·117
—	Arch of Septimius Severus	23·097	2·877	0·117

2548. The recommendation of Vitruvius (lib. iii. c. 2.) to give different degrees of diminution to columns of different heights has been combated by Perrault in his notes on the passage; and we are, with Chambers, of opinion that Perrault is right in his judgment, inasmuch as the proper point of view for a column fifty feet high ought not to be at the same distance as for one of fifteen, the point being removed more distant as the column increases in height, and therefore the apparent relation between the upper and lower diameters would appear the same. "When, therefore," observes Chambers, "a certain degree of diminution, which by experience is found pleasing, has been fixed upon, there will be no necessity for changing it, whatever be the height of the column, provided the point of view is not limited; but in close places, where the spectator is not at liberty to choose a proper distance for his point of sight, the architect, if he inclines to be scrupulously accurate, may vary. Though it is, in reality, a matter of no importance, as the nearness of the object will render the image thereof indistinct, and, consequently, any small alteration imperceptible." Our author afterwards adds: "It must not, however, be imagined that the same general proportions will in all cases succeed. They are chiefly collected from the temples and other public structures of antiquity, and may by us be employed in churches, palaces, and other buildings of magnificence, where majesty and grandeur of manner should be extended to their utmost limits, and where, the composition being generally large, the parts require an extraordinary degree of boldness to make them distinctly perceptible from the proper general points of view."

SUBDIVISION OF ENTABLATURES.

2549. We have spoken of the entablature as the fourth part of the height of the column. In general terms, its subdivisions of architrave, frieze, and cornice are obtained by dividing its height into ten equal parts, whereof three are given to the architrave, three to the frieze, and four to the cornice; except in the Doric order, in which the whole height of the entablature is divided into eight parts, of which two are given to the architrave, three to the frieze, and three to the cornice. From these general proportions variations have been made by different masters, but not so great as to call for particular observation. They deviate but little from the examples of antiquity; and the ease with which they may be recollected render them singularly useful.

MODE OF MEASURING THE ORDERS.

2550. Several methods have been used for forming the scale of equal parts, by which the orders are measured; but they are all founded on the diameter of the column at the bottom of the shaft; for those that use the module or semi-diameter as the measuring unit (which all have done in the Doric order) must still recur to the diameter itself. The authors have also usually divided it into thirty parts, but all concur in measuring by an unit founded on the diameter. We shall follow the practice of Vignola in describing the orders, that master dividing the diameter into two equal parts, of which each is the unit of the scale for profiling the order. The *module* for the two first orders, the Tuscan and Doric, is divided into twelve parts or *minutes;* and for the Ionic, Corinthian, and Composite orders into eighteen parts, by which minute fractions are avoided.

2551. For drawing or *profiling*, as it is called, an order, the proper way is to set out the height of the leading parts and their projections, and then proceed to the subdivisions of each. As a general rule, we may mention that it is usual to make projections of cornices nearly or quite equal to their heights.

APPLICATION OF THE ORDERS.

2552. The application of the orders among the ancients was exceedingly extensive. Porticoes abounded about their cities; their temples were almost groves of columns, with which also were profusely decorated their theatres, baths, basilicæ, and other public buildings, as were no less the courts, vestibules, and halls of their private dwellings. The moderns have in a great measure imitated their example, and their use has very much exceeded the limits of propriety. The maxim of Horace, " Nec Deus intersit," has in no case been more violated by architects than in the unnecessary introduction of the orders on the façades of their buildings. The test of fitness being applied to their employment is the best that the young architect can adopt.

Sect. III.

THE TUSCAN ORDER.

2553. The reader, in *fig.* 877., has before him the geometrical representation of the Tuscan order and its details. A shows the plan of the sofite of the cornice, and B is a plan of the capital. The example is from Vignola's profile, whereon we consider it proper to remark, in conformity with an opinion before expressed (2532, 2533.), that the ovolo which crowns the cornice is an improper moulding for the situation it occupies. The substitution for it of a fillet and cyma recta would have been much more suitable, and would have also been more pleasant in effect.

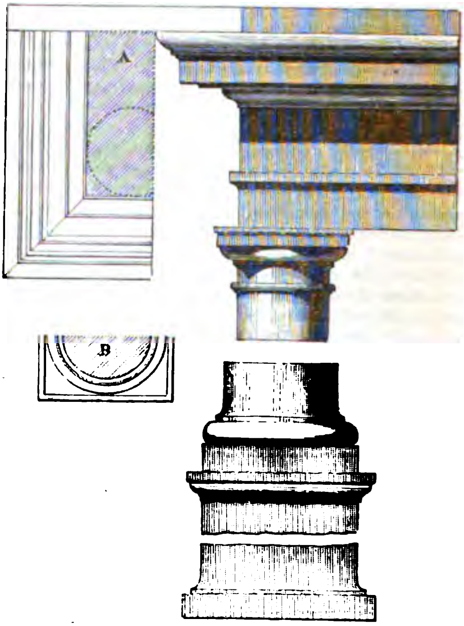

Fig. 877.

2554. " The Tuscan order," says Chambers, " admits of no ornaments of any kind; on the contrary, it is sometimes customary to represent on the shaft of its column rustic cinctures, as at the Palace Pitti in Florence, that of the Luxembourg in Paris, York Stairs in London, and many other buildings of note. This practice, though frequent, and to be found in the works of many celebrated architects, is not always excusable, and should be indulged with caution, as it hides the natural figure of the column, alters its proportions, and affects the simplicity of the whole composition. There are few examples of these bandages in the remains of antiquity, and in general it will be advisable to avoid them in all large designs, reserving the rustic work for the intercolumniations, where it may be employed with great propriety, to produce an opposition which will help to render the aspect of the whole composition distinct and striking." Our author proceeds to observe, that " in smaller works, of which the parts being few are easily comprehended, they may be sometimes tolerated, sometimes even recommended, as they serve to diversify the forms, are productive of strong contrasts, and contribute very considerably to the masculine bold aspect of the composition." Le Clerc allows their propriety in the gates of citadels and prisons, and also considers them not out of place for gates to gardens or parks, for grottoes, fountains, and baths. Delorme made abundant use of them in several parts of the Thuilleries, covering them with arms, cyphers, and other enrichments. They are to be found in the detail of the Louvre, with vermiculated rustics. De Chambrai, who banishes the Tuscan order to the country, nevertheless admits that the Tuscan column may be consecrated to the commemoration of great men and their glorious actions, instancing Trajan's column, one of the proudest monuments of Roman splendour, as also the Antonine column.

2555. Having adjusted the size of the module with its subdivisions of twelve parts, so that the paper or other material on which the order is profiled may contain the whole of the order, it always being understood that the representation for practical purposes need not include the whole height of the shaft of the column, whose minutiæ of diminution may form the subject of a separate drawing, the first step is to draw a perpendicular line for the axis of the column. Parallel to the base lines are then to be drawn, according to the dimensions (parts of the module) given in the table subjoined; and the beginner, as well as the more practised man, is recommended not to set up these as they are given separately, but in every case to add the succeeding dimensions to those preceding rather than to set them off one by one, which, on a small scale, causes minute errors in reading off from the scale to become in the end large in amount. By the adoption also of such a practice the work corrects itself as it proceeds. As the heights are set up, the projection of each member from the axis of the column is to be set off, and this should be always done on both sides at the same time, by which *gulling* of the paper from the point of the compasses, and errors in other respects, are avoided. The *fig.* 878. is

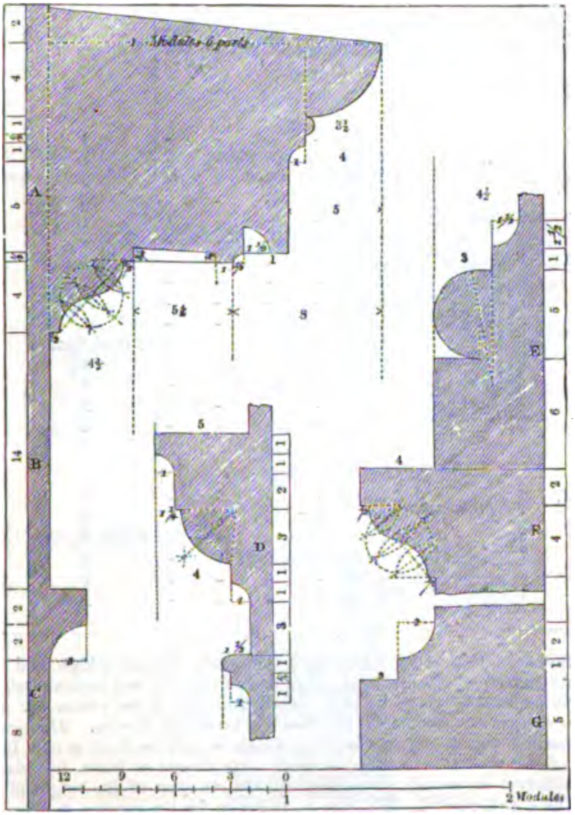

Fig. 878.

but the detail on a larger scale of the general representation exhibited in that preceding The measures of each part are given in the following table.

Table of the Parts of the Tuscan Order.

Mouldings whereof the Parts are composed.			Heights of Mouldings in Parts of a Module.	Projection from the Axis of Column in Parts of a Module.
Entablature.				
Cornice A, 16 parts.	Cymatium, and parts.	Quarter round	4	27½
		Astragal	1	
		Fillet	½	23½
		Congé, or cavetto	1	22½
		Corona	5	22½
		Drip	1	21½
		Sinking from corona, or hollow	½	19½
		Fillet	½	14
	Bed moulding	Ogee	4	13½
Frieze B, 14 parts.			14	9½
Architrave C, 12 parts.	Fillet.	Fillet, or listel	2	11½
	Fascia.	Congé, or small cavetto	2	9½
		Fascia	8	9½
The height of the drip under the corona is taken on that member, and that of the hollow in the height of the fillet.				
Column.				
Capital D, 12 parts.	Abacus.	Fillet	1	14½
		Congé, or cavetto	1	13½
		Band	2	13½
	Cymatium.	Ovolo	3	13¾
		Fillet	1	10½
		Congé, or cavetto	1	9½
	Neck, or Hypotrachelion		3	9½
Shaft, 12 modules.	Astragal, or necking.	Bead	1	11
		Fillet	½	10½
		Congé, or cavetto	1	9½
	Shaft.	Shaft	11 mod. 8 parts.	9½
		Congé, or apophyge	1½	12
Base, E, 12 parts.		Fillet	1	13½
		Torus	5	16½
		Plinth	6	16½
Pedestal.				
Cornice G, 6 parts.	Cymatium.	Listel	2	20½
		Ogee	4	20
Die F, 44 parts.		Die, or dado	3 mod. 4 parts.	16½
		Congé, or apophyge	2	16½
Base, 6 parts.		Fillet	1	18½
		Plinth	5	20½

2556. Vitruvius in this order forms the columns six diameters high, and makes their diminution one quarter of the diameter. He gives to the base and capital each one module in height. No pedestal is given by him. Over the capital he places the architrave of timber in two thicknesses connected together by dovetailed dowels. He however leaves the height unsettled, merely saying that their height should be such as may be suitable to the grandeur of the work where they are used. He directs no frieze, but places over the architrave cantilevers or mutuli, projecting one fourth part of the height of the column, including the base and capital. He fixes no measure for the cornice, neither does he give any directions respecting the intercolumniations of this order. The instructions are not so specific as those which he lays down for the other orders, and there have been various interpretations of the text, which unfortunately cannot in any of the suppositions be tested on ancient remains. The whole height, according to the measuring unit which we have adopted from Vignola, is 16 modules and 3 parts.

2557. Palladio makes the height of his Tuscan column 6 diameters, and diminishes the shaft one fourth of a diameter. The height of the base and capital are each half a diameter. He provides no pedestal, but, instead thereof, places the base of the column on a zocalo or lofty plinth, whose height is equal to the diameter of the column. He leaves the intercolumniation unsettled, merely hinting that as the architraves are of timber, they, the intercolumniations may be wide. The whole height by him assigned to the order is 9 diameters and three quarters of the column. The whole height according to our scale is 19 modules and 6 parts.

2558. Serlio makes the column of the order 5 diameters exclusive of base and capital, each of which are half a diameter in height, and his diminution is one quarter of the diameter. He gives half a diameter to the height of the architrave, and an equal height to the frieze and to the cornice. His pedestal is with a plinth and base, a die, and cymatium, the whole being a third of the height of the column. He gives no rules for the intercolumniations, though in book 4. he inserts a diagram wherein intercolumns appear, merely saying that they are equal to 3 diameters. The total height according to our measure is 19 modules and 3 parts.

2559. Scamozzi makes the shaft of his column 6 diameters, and diminishes it one fourth part of its diameter. The heights of the base and capital are each half a diameter. To the entablature he assigns for height one fourth of the height of the column, including its base and capital, less half its diameter. He places a sort of triglyph in the frieze, which arises from a misconception of the text of Vitruvius. The height of his pedestal is a fourth part of that of the column, with base and capital, less half a diameter. The whole height in our measure is 21 modules and 9 parts.

Sect. IV.

THE DORIC ORDER.

2560. The Doric order of the moderns is of two sorts: mutular and denticular, the former is represented in *fig.* 879. A is a plan of the sofite of the corona; B, a plan of the capital; and C, a plan of the base. In the frieze the channelled projections are called *triglyphs*, and the spaces between them *metopæ*, which should in breadth be equal to their

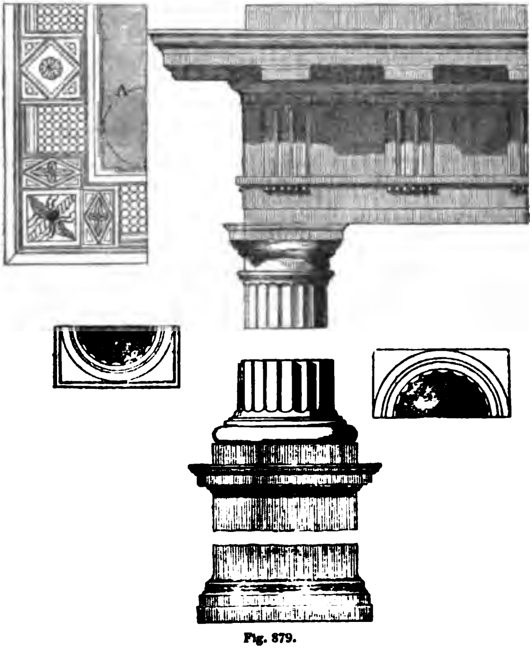

Fig. 879.

height, which is that of the frieze. The shaft is usually channelled with twenty *flutes.* Over the triglyphs are distributed *mutules* or modillions, and another peculiarity is the introduction of *guttæ* or *drops*, which decorate the sofite of the cornice and the feet of the triglyphs.

2561. Daviler, speaking of the two Doric entablatures given by Vignola, admires the elegance of their composition, and scarcely knows which of them to select as the most beautiful. "The first" (or denticular), hereafter immediately subjoined, says Chambers, following that author, "which is entirely antique, is the lightest, and consequently properest for interior decoration or objects intended for near inspection; the other, composed by Vignola himself from various fragments of antiquity, being bolder, and consisting of larger parts, seems better calculated for outside works and places where the point of view is either distant or unlimited. On polygonal plans, however, the mutule cornice must be avoided, because the sofites of the angular mutules would form irregular and very disagreeable figures: neither should it be employed in concaves of small dimensions, for the same reason; nor in places where frequent breaks are requisite, it being extremely difficult, often impossible, to prevent the mutules from penetrating and mutilating each other in various unsightly manners; and wherever this cornice is used on a convex surface, the sides of the mutules must be made parallel, for it would be both disagreeable and unnatural to see them broader, and consequently heavier in front than where they spring out of the mutule band." We have elsewhere observed that there is very great difficulty in distributing the parts of the Doric entablature, on account of the intervals between the centres of the triglyphs, which necessarily confine the composer to intercolumniations divisible by two modules and a half, thus producing spaces which are often too wide or too narrow for his purposes.

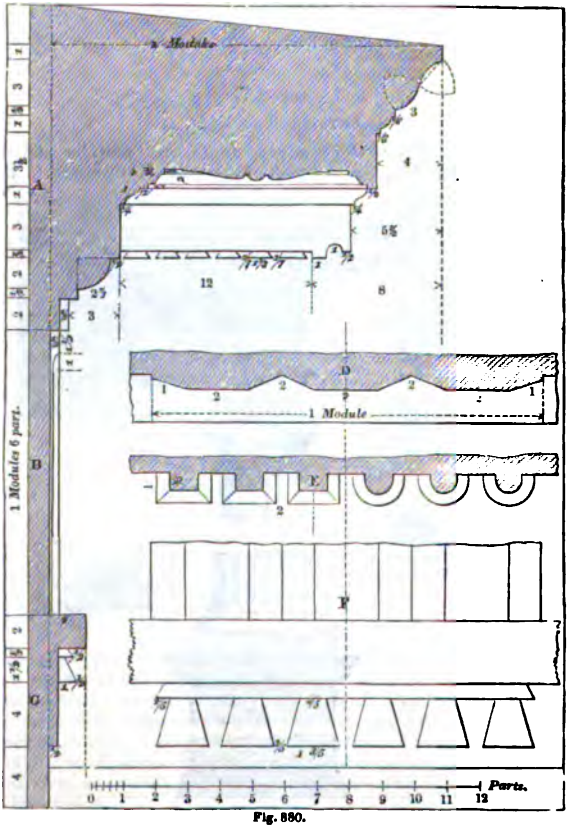

Fig. 880.

2562. In *fig.* 880. the entablature of the mutular Doric order is given to a larger scale than that of the preceding figure; and we subjoin, as in the Tuscan order, —

Table of Parts of the Entablature of the Mutular Doric.

Mouldings whereof the Parts are composed.		Heights of Mouldings in Parts of a Module.	Projections from Axis of Column in Parts of a Module.
Cornice A, 18 parts.	Fillet of the corona	1	34
	Cyma	3	31
	Fillet	½	31
	Cyma reversa	1	30¾
	Corona	3½	30
	Cyma reversa	1	29½
	Mutule	3	28½
	Drip	½	28
	Gutta of the mutule	½	26
	Echinus, or quarter round	2	13½
	Fillet	½	11½
	Capital of the triglyph	2	11
Frieze B, 18 parts.	Triglyph	18	10½
	Metope	18	10
Architrave C, 12 parts.	Listel	2	12
	Capital of the guttæ	½	11½
	Guttæ	1½	11½
	First fascia	6	10½
	Second fascia	4	10

D is the plan of a triglyph to double the scale.
E is the plan of the round or square guttæ.
F is the elevation of the triglyph and its guttæ.

2563. To obviate the difficulties mentioned in 2561. relative to the triglyphs, they have often been omitted and the entablature left plain, as in the Coliseum at Rome, the colonnades of St. Peter's of the Vatican, and in many other buildings. This, says Chambers, is an easy expedient; but as it robs the order of its principal characteristic distinction, the remedy is a desperate one, and should only be employed as a last resource.

2564. The Doric order was used by the ancients in temples dedicated to Minerva, to Mars, and to Hercules. In modern buildings, Serlio (lib. iv. c. 6.) recommends it in churches dedicated to saints remarkable by their suffering for the Christian faith. Le Clerc suggests its use for military buildings. "It may," says Chambers, "be employed in the houses of generals, or other martial men, in mausoleums erected to their memory, or in triumphal bridges and arches built to celebrate their victories."

2665. As the difference between the mutular and denticular Doric lies entirely in the entablature, we give in the following table the whole of the details of the order, observing, that from the capitals downwards, the measures assigned to them are the same for each. *Fig.* 881. represents the entablature of the denticular Doric and its parts,

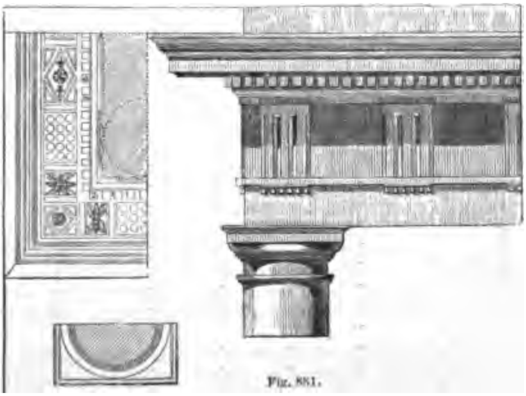

Fig. 881.

which, with those of the capital, base, and pedestal, are in *fig.* 882. given to a larger

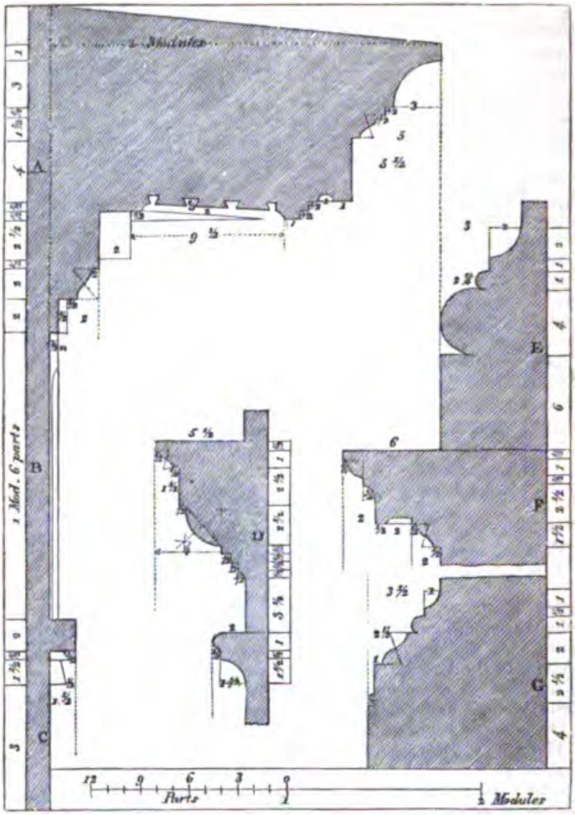

Fig. 882.

scale, as we have before represented the parts of the Tuscan order. The general table is subjoined: —

Members composing the Order.		Heights in Parts of a Module.	Projections in Parts of a Module from Axis of Column.
	ENTABLATURE.		
A, Cornice, 18 parts.	Fillet of corona - - -	1	34
	Cavetto - - - -	3	31
	Fillet - - - - -	¼	26
	Cyma reversa - - - -	1½	30
	Corona - - - -	4	28½
	Drip - - - - -	½	27½
	Fillet - - - - -	½	25
	Gutta under the corona - -	½	24½
	Dentil - - - -	3	15
	Fillet - - - - -	½	13
	Cyma reversa - - - -	2	12½
	Capital of triglyph - - -	2	11
B, Frieze, 18 parts.	Triglyph - - - -	18	10½
	Metope - - - -	18	10

Members composing the Order.		Heights in Parts of a Module.	Projections in Parts of a Module from Axis of Column.
C, Architrave, 10 parts.	Listel	2	11½
	Capital of guttæ	½	11
	Guttæ	1½	11
	Fascia	10	10
Column.			
D, Capital, 12 parts.	Listel	½	15½
	Cyma reversa	1	15¼
	Band	2½	14
	Echinus or quarter round	2½	13¾
	Three annulets	1½	11½
	Neck of capital	4	10
	Astragal: Ovolo	1	12
	Astragal: Fillet	½	11½
	Astragal: Congé	1½	10
Shaft of the Column, 14 modules.			
E, Base, 12 parts.	Apophyge or congé	2	12
	Fillet	⅔	14
	Astragal	1⅓	14¾
	Torus	4	17
	Plinth	6	17
Pedestal.			
F, Cornice, 6 parts.	Listel	½	23
	Echinus	1	22¾
	Fillet	½	21¾
	Corona	2½	21
	Cyma reversa	1½	18½
Die of the Pedestal, 4 modules.			
G, Base, 10 parts.	Congé	1	17
	Fillet	½	18
	Astragal	1	18¾
	Inverted cyma	2	19
	Second plinth	2½	21
	First plinth	4	21½

2566. Vitruvius, with more clearness than in the others, describes the Doric order. In order to set out its proportions, he tells us (book iii. chap. iii.), though not giving a direct rule, that its pedestal is composed of three parts, the cymatium or cornice, the die, and the base; and that the base and cimatium are composed of many mouldings, whose individual proportions however he does not give. He assigns no particular base to the Doric order; but, nevertheless, places under half a diameter in height the attic base, whose members are the plinth, small fillet, scotia, and the upper torus with its superior and inferior fillets, together with the apophyge of the column. He gives to the projection of the base a fifth part of the diameter of the column. The height of the shaft he makes of 6 diameters, and its dimunition a sixth part of the diameter. The capital's height he makes equal to half a diameter, and calls the neck the frieze of the column. To the architrave he assigns the height of one half diameter of the column, and to the frieze 50 parts of his module (semidiameter divided into 30 parts), including the fascia, forming the capital of the triglyphs. His cornice consists of 30 parts of the module, and its projection 40. The whole height which he gives to the order is, in the measure here adopted, 17 modules and 20 parts.

2567. Palladio makes the Doric pedestal rather less than 2¼ diameters of the column, dividing it into three parts, the base, die, and cymatium. To the die he assigns nearly a diameter and one third of the column. To the cymatium a little more than one third of the diameter. He uses the attic base to the order, but, for the sake of carrying off the water, turns the plinth into an inverted cavetto (*guscio*), ending in the projection of the cymatium of the pedestal. To the shaft of the column he assigns various proportions, directing that if accompanied with pilasters, it should be of the height of $8\frac{5}{12}$ diameters, and if entirely isolated, 7 or at most 8 diameters high. He cuts the shaft into 24 flutes, and diminishes it the tenth part of its diameter. The height of his capital is half a diameter, and, like Vitruvius, he decorates the neck or frieze, as they both call it, with roses, adding, however, other flowers, and making its projection a little more than a fifth part of the diameter. To the architrave, frieze, and cornice he gives a little more than one fourth part of the height of the column, so that the whole height of his order is in our measure 24 modules and a fraction above 2¼ parts.

2568. Serlio makes the height of the pedestal of his column a little less than 3 diameters, with its base, die, and cymatium. The height of the die is set up equal to the diagonal of a square, formed on the plinth of the column. The height of the cymatium, according to the strict text of Serlio, should not be less than that of the base; but he altogether omits any mention of its projection. His base is the attic base, to which he assigns a projection of a quarter of a diameter. The column is 6 diameters high, and has 20 flutes. His capital differs only from that of Vitruvius in its projection, which is rather more. The architrave and frieze do not much differ from those already described. The projection given to the cornice is equal to its height. The whole height in our measures amounts to 23 modules and 5 parts.

2569. The Doric order as described by Scamozzi is not very dissimilar to those already described. The pedestal is by him made 2 diameters and a little more than a quarter, with a base, die, and cymatium, and the projection barely a quarter of the diameter of the column, to which he gives the attic base. His column is $7\frac{1}{3}$ diameters high, and the diminution a fifth part of the diameter. There are 26 flutes on the shaft, separated from each other by fillets, whose width is one third of the flute. This author gives three different sorts of capitals for the order: the first has three annulets; the second has only the lower annulet, the two upper ones being changed to an astragal; the third, instead of the two lower annulets, has a cyma reversa. Lastly, above the corona he places a cyma reversa, and in the other parts does not vary much from the preceding authors, especially in the frieze and architrave, except that in the last he uses two fasciæ. To the cornice he assigns the projection of five sixths of a diameter of the column. His whole entablature is a little less than one fourth the height of the column, including base and capital. The whole height of the order in our measures is 13 modules and 8 parts.

2570. In *fig.* 883. the profile of the Grecian Doric from the Parthenon at Athens is given. Though very different to those we have already described of this order, the resemblance is still considerable. Its character is altogether sacred and monumental, and its application, if capable of application to modern purposes, can scarcely be made to any edifice whose general character and forms are not of the severest and purest nature. The various absurd situations in which the Grecian Doric has been introduced in this country, has brought it into disrepute; added to which, in this dark climate the closeness of the intercolumniations excludes light, which is so essential to the display of architecture under the cloudy skies with which we are constantly accompanied in high latitudes. The diameter of the columns in the original is 6 feet 2·7 inches.

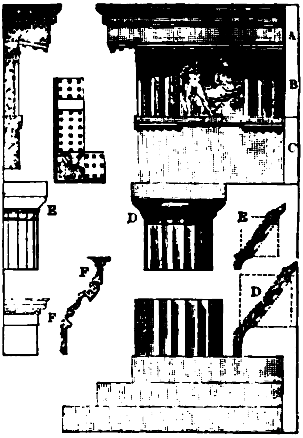

Fig. 883.

2571. Lest we may be reproached with neglecting to submit to the student in this place (and the remark equally applies to the following section on the Ionic order) more examples of the Grecian Doric, we would here observe that this work is not to stand in place of a parallel of the orders. Nothing would have been easier than to have placed before him an abundance of examples; but they must be sought elsewhere, inasmuch as the nature of our labours requires general, not special, information in this respect. We have not, however, refrained in the first book (142, *et seq.*) from entering into details respecting the Grecian Doric, which we consider much more valuable to the reader than would be the exhibition of a series of profiles of its principal examples. We have, moreover, at that place, suggested some criteria of their comparative antiquity. We do not think the nice copying of a profile into a modern work any other than a disgraceful exhibition of the want of ability in the man, we cannot call him artist, who adopts it, and shall be much better pleased to leave the student in doubt, so that he may apply himself *pro re natâ* to the matter which calls his genius into play. From what we have said on *the orders* in Sect. II. of this Book, (2523, *et seq.*), relative to the order, and on *mouldings*

(2532, *et seq.*), it must be quite clear that the variety of every order, keeping to first principles, has not been yet exhausted, neither is it likely to be so.

TABLE OF THE PARTS OF THE GRECIAN DORIC (PARTHENON).

Members composing the Order.		Heights in Parts of a Module and Decimals.	Projections in Parts of a Module from Axis of Column.
ENTABLATURE.			
A, Cornice, 15·32 parts.	Fillet - - - - - -	0·60	22·10
	Echinus - - - - -	3·12	20·40
	Fillet, with sunk cyma reversa -	2·20	
	Corona - - - - -	4·88	18·98
	Fillet - - - - - -	1·10	18·80
	Capital of mutules - - -	1·10	
	Mutules - - - - -	0·32	18·66
	Bead and capital of triglyphs - -	2·00	11·46
B, Frieze, 30·00 parts.	Frieze (in metope) - - -	15·12	
	Triglyph - - - - -	14·88	11·40
C, Architrave, 17·10 parts.	Fillet - - - - - -	1·50	12·50
	Cap of guttæ - - - -	1·00	12·40
	Guttæ - - - - -	0·20	
	Architrave below guttæ - -	14·40	11·20
COLUMN.			
D, Capital, 11·16 parts	Abacus - - - - -	4·40	12·90
	Echinus - - - - -	3·60	12·60
	Fillets and hollows, with cavetto -	0·80	
	Neck - - - - - -	2·20	9·44
	Groove or sinking - - -	0·16	
	Shaft - - - - - -	20·30	at top 9·38 at bottom 12·00
	First step or plinth - - -	6·90	12·80
	Second step or plinth - - -	6·70	21·80
	Third step or plinth - - -	6·90	30·84

2572. The minutiæ of the Grecian Doric, as we have just observed, cannot be given in a general work of this nature. In its smaller refinements it requires plates on a much larger scale than this volume allows. The reader, therefore, must be referred to *Stuart's Antiquities of Athens* (original edition), and the publications of the Dilettanti Society, for further information on the subject of the Grecian Doric. All that was here possible was to give a general idea of the order. In the figure, E is the section of the capitals of the inner columns of the temple on a larger scale. DD relate to the principal columns. F is a section of one of the antæ or pilasters to double the scale of the capital. The intercolumniations are of 8 modules, 8·20 parts, from axis to axis of column. The principal Grecian Doric examples are — the Parthenon, the temple of Theseus, the propylæa and the portico of the Agora at Athens; the temple of Minerva at Sunium; the temple at Corinth; of Jupiter Nemæus, between Argos and Corinth; temple of Apollo and portico of Philip in the island of Delos; the temple of Jupiter Panhellenius at Egina, and of Apollo Epicurius at Phigalia; the two temples at Selinus; that of Juno Lucina and Concord at Agrigentum; the temple at Egesta, and the three temples at Pæstum. (See 142, *et seq.*)

SECT. V.

THE IONIC ORDER.

2573. Of the Ionic order there are many extant examples, both Grecian and Roman; and, except the debased later examples of the latter, there is not that wide difference between them that exists between the Grecian and Roman Doric. The Ionic has been considered as deficient in appearance as compared with the other orders, on account of the irregularity of its capital, which, on the return, presents difficulties in use. These difficulties are not obviated by the practice of the Greeks, who made an angular volute on each extremity of the principal façade, and then returned the face of the capital. With all our respect for Greek art, we think the expedient, though ingenious, a deformity; albeit, in the case of the type being a timber architrave, we must admit that the face of the capital should lie in the direction of the superincumbent beam.

2574. In the example given (*fig.* 884.) we have, as in the examples of the preceding orders, selected the profile of Vignola as the most elegant of the moderns; and the reader will here recollect that in the Ionic, Corinthian, and Composite orders, the module or semi-diameter of the column is divided into 18 parts. In the figure, A is a plan of the sofite of the cornice, and B a plan of the capital. The method of tracing the volute will be given in a subsequent figure: previous to which, as in the orders already given, we subjoin a table, showing the heights and projections of the parts of the order.

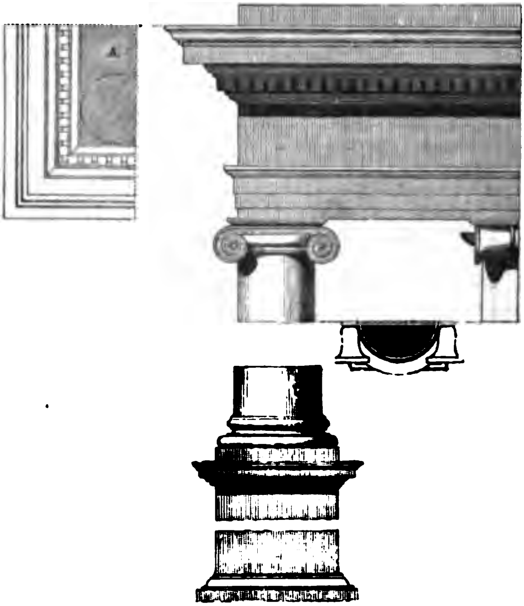

Fig. 884.

Members composing the Order.		Heights in Parts of a Module.	Projections from Axis of Column in Parts of a Module.
	Entablature.		
A, cornice, 34 parts.	Fillet of cyma	1½	46
	Cyma recta	5	
	Fillet	½	41
	Cyma reversa	2	40½
	Corona	6	38½
	Fillet of the drip	1	29¼
	Ovolo	4	28¼
	Astragal	1	25
	Fillet	½	24½
	Dentel fillet	1½	21
	Dentels	6	24
	Fillet	1	20
	Cyma reversa	4	19½
B,	Frieze	27	15

Members composing the Order.		Heights in Parts of a Module.	Projections from Axis of Column in Parts of a Module.
C, Architrave, 22½ parts.	Listel	1½	20
	Cyma reversa	3	19⅔
	First fascia	7½	17
	Second fascia	6	16
	Third fascia	4½	15
D,	Capital on the side	19	20
	Capital on the coussinet, or cushion	16	17½
	COLUMN.		
E, Capital, 17 parts.	Fillet	1	20
	Cyma reversa	2	19½
	Listel	1	17½
	Channel of the volute	3	17
	Ovolo	5	22
	Astragal: Bead	2	18
	Astragal: Fillet	1	17
	Astragal: Congé, or cavetto	2	15
	Shaft of the column: above	- -	15
		16 mod. 6 parts.	
	Shaft of the column: below	- -	18
	Apophyge	2	18
F, Base, 19½ parts.	Fillet	1½	20
	Torus	5	22½
	Fillet	¼	20½
	Scotia	2	20
	Fillet	¼	22
	Two beads	2	22½
	Fillet	¼	22
	Scotia	2	21
	Fillet	¼	24
	Plinth	6	25
	PEDESTAL.		
G, Cornice, 11¾ parts.	Fillet	¾	35
	Cyma reversa	1¼	34¾
	Corona	3	33½
	Fillet of the drip	½	30
	Ovolo	3	29½
	Bead	1	27
	Fillet	1	26¼
	Congé	1¼	25
	Die, 4 modules	12¾	1 mod. 7.
H, Base, 10 parts.	Congé	2	25
	Fillet	1	27
	Bead	1½	28
	Cyma reversa	3	27½
	Fillet	⅔	31⅔
	Plinth	4	33

The flutes in this order are separated by a listel.

2575. The letters to the leading divisions of the above table refer to the *fig.* 885. wherein the parts are drawn to a larger scale, and wherein I is the eye of the volute, presently to be described.

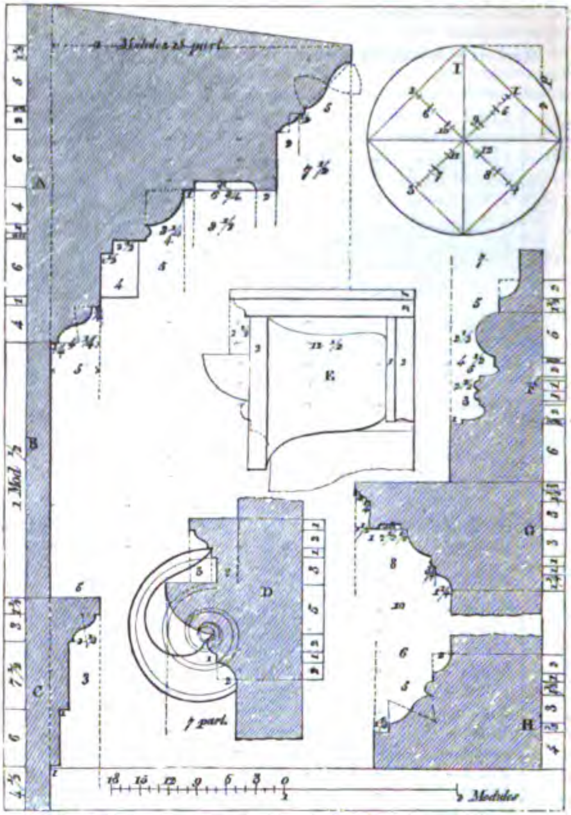

Fig. 885.

2576. *Fig.* 886. shows the method of drawing the volute, the centre of whose eye, as it is called, is found by the intersection of an horizontal line from E, the bottom of the

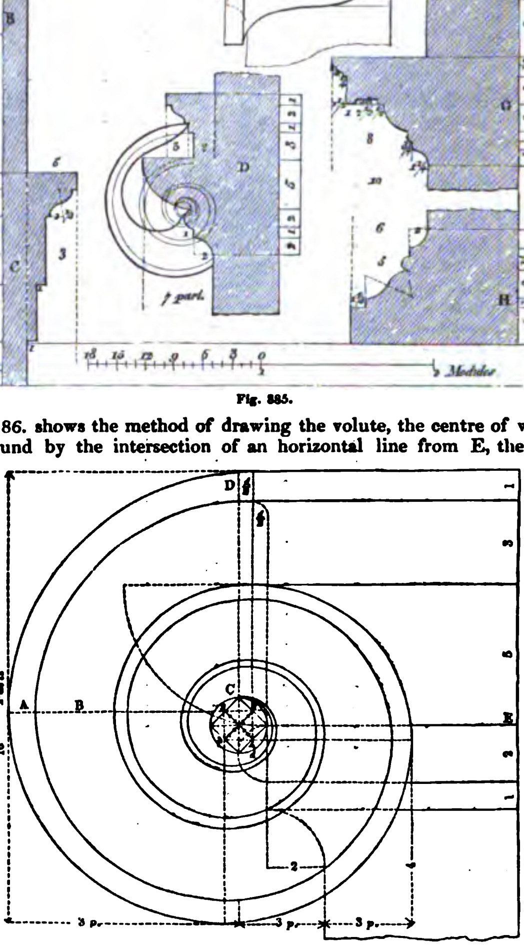

Fig. 886.

echinus, with a vertical from D, the extremity of the cyma reversa. On the point of intersection, with a radius equal to one part, describe a circle. Its vertical diameter is called the *cathetus*, and forms the diagonal of a square, whose sides are to be bisected, and through the points of bisection (see I, *fig.* 885.) the axes 1, 3 and 2, 4 are to be drawn, each being divided into 6 equal parts. The points thus found will serve for drawing the exterior part of the volute. Thus, placing the point of the compasses in the point 1, with the radius 1D, the quadrant DA is described. With the radius 2A another quadrant may be described, and so on. Similarly, the subdivisions below the points used for the outer lines of the volute serve for the inner lines. The total height of the volute is 16 parts of a module, whereof 9 are above the horizontal from E, and 7 below it.

2577. Vitruvius, according to some authors, has not given any fixed measures to the pedestal of this order. Daniel Barbaro, however, his commentator, seems to think otherwise; and, on this head, we shall therefore follow him. The height of the pedestal is made nearly a third part (including its base and cymatium) of the height of the column. To the base of the column he assigns half a diameter, and to the shaft itself nearly 8 diameters, its surface being cut into 24 flutes, separated by fillets from each other. His method of describing the volute is not now thoroughly understood; and it is, perhaps, of little importance to trouble ourselves to decypher his directions, seeing that the mode of forming it is derived from mathematical principles, as well understood now as in the days of the author. The architrave he leaves without any fixed dimensions, merely saying that it must be larger or smaller according to the size of the edifice. He prescribes, however, that the architrave, frieze, and cornice should together be somewhat less than a sixth part of the height of the column, with its base and capital. The total height he makes the order, according to our measures, is 25 modules and nearly 9 parts.

2578. Palladio gives to the pedestal 2 diameters and nearly two thirds of the height of the column. He adopts the attic, though without rejecting the Ionic base, and makes it half a diameter high, adding to it a small bead, which he comprises in the height of the shaft, which he makes 8 diameters in height. To the architrave, frieze, and cornice, taken together, he assigns a little less than one fifth of the height of the column, including its base and capital, and makes the projection of the cornice equal to its height. The total height of the order, in our measures, is, according to him, 27 modules and nearly 8 parts.

2579. Serlio, in this order more than any of the others, varies from Vitruvius. To the pedestal he gives, including base, die, and cymatium, a little more than a third part of the height of the column, with its base and capital. To the shaft of the column he gives 7 diameters, and diminishes it a sixth part of its diameter. His capital is that of Vitruvius, as far as we can understand that master. His mode of constructing the volute differs from other authors. His directions are, that having found the cathetus, which passes through the centre of the eye, it must be divided into eight parts, from the abacus downwards, one whereof is to be the size of the eye of the volute, four remain above the eye, and three below that part comprised below the eye. The cathetus is then divided into six parts, properly numbered by figures from 1 to 6. With one point of the compasses in 1, and the other extended to the fillet of the volute, he describes a semicircle, and so on with semicircles consecutively from 2 to 6, which will ultimately fall into the eye of the volute. We cannot speak in high terms of Serlio's method, and therefore have thought it unnecessary to accompany the description with a figure. It is rather a clumsy method, and we fear, if exhibited in a figure, would not satisfy our readers of its elegance. The height of his architrave, frieze, and cornice together is a little less than a fourth part of the height of the column, including the base and capital. The whole height of his order, in our measures, is 25 modules and 6 parts.

2580. Scamozzi directs that the pedestal shall be with its base and cornice two diameters and a half of the column. He uses the attic base, and, like Palladio, gives an astragal above the upper torus. To the shaft of the column he assigns a height of little less than 8 diameters, and makes its diminution a sixth part of the diameter. He adopts the angular capital, something like the example of that in the temple of Fortuna Virilis. The height of his architrave, frieze, and cornice is a little less than a fifth part of the height of the column, with its base and capital. The total height of his order, in our measures, is 26 modules.

2581. The principal examples of the Grecian Ionic are in the temples of Minerva Polias, of Erectheus, and the aqueduct of Hadrian, at Athens; in the temple of Minerva Polias at Priene; of Bacchus at

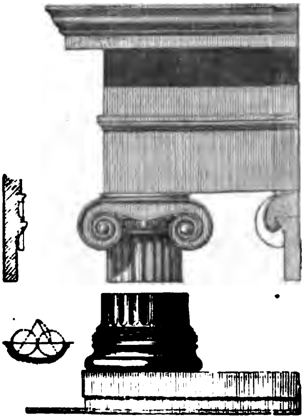

Fig. 887

Teos; of Apollo Didymæus at Miletus; and of the small temple on the Ilyssus, near Athens, whereof in *fig.* 887. the profile is given, and below, a table of the heights and projections of the parts. It is to be observed, that in the Grecian Ionic volute the fillet of the spiral is continued along the face of the abacus, whilst in the Roman examples it rises from behind the ovolo. Some of the Athenian examples exhibit a neck below the echinus, decorated with flowers and plants. The entablatures of the early Ionic are usually very simple. The architrave has often only one fascia, the frieze is generally plain, and the cornice is composed of few parts. In Book I. Chap. II. (153, *et seq.*) we have already examined the parts of the Grecian Ionic, and thereto refer the reader.

TABLE OF THE PARTS OF THE GRECIAN IONIC IN THE TEMPLE ON THE ILYSSUS.

Members composing the Order.		Heights in Parts of a Module and Decimals.	Projections in Parts of a Module from Axis of Column.
	ENTABLATURE.		
Cornice, supposed height 18·33 parts.	Fillet	restored.	restored.
	Cyma recta	restored.	restored.
	Fillet	restored.	restored.
	Echinus	2·040	34·440
	Corona	6·240	33·960
	Drip	4·680	
	Cyma reversa	2·700	20·520
	Fillet	0·720	
	Echinus	1·260	18·360
	Frieze	29·901	17·400
Architrave, 33·66 parts.	Fillet	1·920	30·520
	Echinus	2·520	20·100
	Bead	1·200	17 880
	Fascia	27·600	17·160
	COLUMN.		
Capital, 19·32 parts.	Echinus	2·040	19·860
	Fillets, or beads of volutes	1·050	
	Channel	7·320	
	Fillets, or beads of volutes	1·050	
	Channel	0·600	
	Cathetus	- -	17·550
	Echinus	4·650	18·960
	Bead	1·080	17·250
	Fillet	0·450	15·720
	Congé	1·080	
	Shaft	17 mod. 7·110	above 15·360 below 18·000
Base, 33·27 parts.	Apophyge	1·080	
	Fillet	0·450	18·960
	Bead	1·080	19·320
	Horizontally fluted torus	6·120	22·500
	Fillet	0·450	22·500
	Scotia	6·000	21·840
	Fillet	0·450	23·640
	Torus	5·760	24·960
	Plinth	11·880	26·520

The height from the top of the echinus to the centre of the eye of the volute is 15·72 parts.

Total projection of the volute from axis of column, 27·90.

The flutes are elliptical on the plan (see *fig.* 887.), and the distance between axes of columns, 6 modules 3·24 parts.

Sect. VI.

THE CORINTHIAN ORDER.

2582. For the Corinthian order, we must seek examples rather in Rome than in any part of Greece. The portico at Athens, and the arch of Hadrian at Athens, do not furnish us with specimens of art comparable with the three columns in the Campo Vaccino, belonging, as is generally supposed, to the temple of Jupiter Stator. Those in the temple near Mylassa, and the Incantata, as it is called, at Salonica, do not satisfy the artist, as compared with the examples in the remains of the temple of Mars Ultor at Rome, the temple of Vesta at Tivoli, and others, for which the reader may refer to Desgodetz.

2583. The reader is again here reminded that the module or semidiameter is to be divided into eighteen parts. In *fig.* 888. is a representation of the Corinthian order, whose measures are given in the following table: —

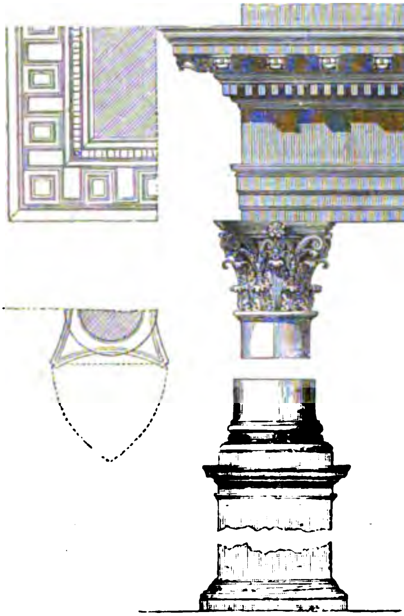

Fig. 888.

Members composing the Order.		Heights in Parts of a Module.	Projections from Axis in Parts of a Module.
	Entablature.		
A, cornice, 38 parts.	Fillet of cornice - - - -	1	53
	Cyma recta - - -	5	53
	Fillet - - - - -	½	48
	Cyma reversa - - -	1½	45½
	Corona - - - - -	5	46
	Cima reversa - - - - -	1½	45½
	Modillion - - - - -	6	44½
	Fillet (remainder of modillion band) -	½	28½
	Ovolo - - - - -	4	28
	Bead - - - - -	1	25
	Fillet - - - - -	½	24½
	Dentils - - - - -	6	24
	Fillet - - - - - -	⅓	20
	Hollow or congé - - -	3	19⅔

Members composing the Order.		Heights in Parts of a Module.	Projections from Axis in Parts of a Module.
B, -	Frieze, 1 mod. 7½ parts high - -	- -	15
C, architrave, 27 parts.	Fillet - - - - -	1	20
	Cyma reversa - - - -	4	19⅔
	Bead - - - - -	1	17
	First fascia - - - -	7	16½
	Cyma reversa - - - -	2	16⅓
	Second fascia - - - -	6	15½
	Bead - - - -	1	15½
	Third fascia - - - -	5	15
	Column.		
D, capital, 42 parts.	Echinus - - - -	2	diagonally 36, on plan 33½,
	Fillet - - - -	1	
	Lower member of abacus - -	3	
	Inverted echinus of the bell - -	2	22⅔
	Large volutes - - - -	6	31⅓
	Upper small leaves - - -	4	
	Large leaves - - - -	12	at top, 24½
	Lower leaves - - -	12	at top, 20½
Shaft, 17 modules 1½ part.	Astragal - - - -	2	18
	Fillet - - - -	1	17
	Congé - - - -	2¼	
	Shaft: Upper part - - -	- -	15
	Shaft: Lower part - - -	- -	18
	Apophyge - - - -	2	20
	Fillet - - - -	1½	21⅝
E, base, 14½ parts.	Torus - - - -	3	22
	Fillet - - - -	¼	20½
	Scotia - - - -	1½	20
	Fillet - - - -	¼	21¾
	Two beads - - - -	1	22
	Fillet - - - -	¼	21⅝
	Scotia - - - -	1½	21⅛
	Fillet - - - -	¼	23
	Torus - - - -	4	25
	Plinth - - - -	6	25
	Pedestal.		
F, Cornice, 14¼ parts.	Fillet - - - -	⅔	33½
	Cyma reversa - - -	1⅓	33¼
	Corona - - - -	3	32
	Throat - - - -	1¼	30¾
	Bead - - - -	1	26½
	Fillet - - - -	¾	25¾
	Frieze - - - -	5	25
	Bead - - - -	1¼	26⅞
Die, 91¼ parts.	Fillet - - - -	¾	26¼
	Congé - - - -	1¼	25
	Die - - - - -	87¼	25
	Fillet - - - -	1¼	25
	Congé - - - -	¾	26¼
G, Base, 14¼ parts.	Bead - - - -	1¼	27½
	Inverted cyma reversa - -	3	26⅞
	Fillet - - - -	1	30¾
	Torus - - - -	3	32½
	Plinth - - - -	6	32½

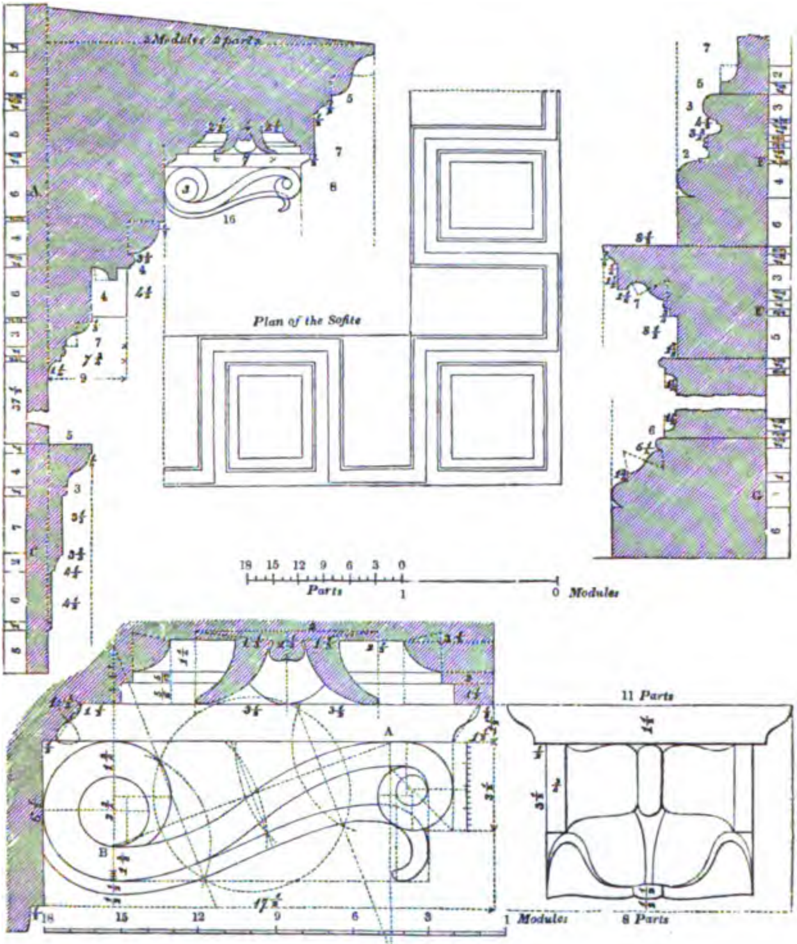

Fig. 889.

2584. *Fig.* 889. shows the details of the entablature, &c. and also the profile and front of the Corinthian modillion to a larger scale. On the profile is shown the caisson or sunk panel on the sofite of the corona. The height is six parts, and the projection sixteen. As seen in the figure, a distance equal to three parts and a half is taken for the height of the smaller volute, and on this distance a scale of sixteen equal parts is made; the figure shows the dimensions to be given to the small squares, whose angles serve as centres to describe the curves. Having drawn the line AB, it is divided into four equal parts by lines perpendicular to it, which, meeting vertical lines from A and B, give the points, which serve as centres for striking the curve of the modillions. The acanthus leaf which supports it, as well as the curves which form the profile of the roses in the caisson, are also struck by compasses.

2285. In *fig.* 890., which exhibits the method of drawing the Corinthian capital, one half of the plan shows the capital in plan, and the other half of it laid down diagonally. Having drawn the axis of the plan correspondent to the axis of the elevation of the capital, with a radius equal to two modules, describe a circle, which divide into sixteen equal parts. Their lines of division will each correspond to the centre of each leaf. The vase of the capital is determined by a circle whose radius is 14½ parts. The figure shows the circles which bound the leaves upwards on the vase.

2586. The elevation shows the heights whereon are carried the projections of the plan.

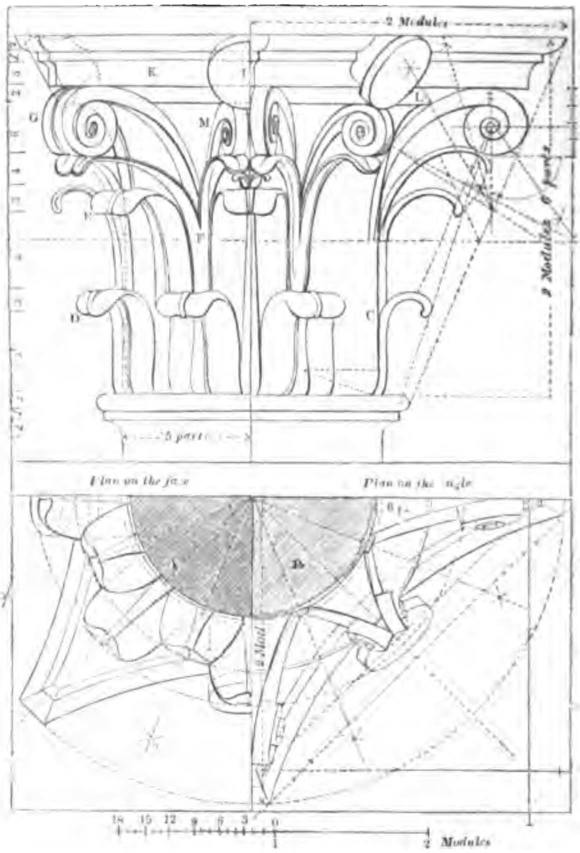

Fig. 890.

Above the leaves come the sixteen volutes, whereof the eight larger ones support the four angles of the abacus, and the eight smaller ones support the flowers which decorate the middle of the abacus. The volutes seen in profile may be drawn geometrically with the compasses, but they are always more agreeable and easy when drawn by the eye with a hand which feels the contours.

The different parts of the capital are as follow: A, plan of the leaves and abacus; B, plan of the larger and smaller volutes; C, the vase or body of the capital; D, the first tier of leaves; E, the second tier of leaves; F, the caulicolus; G, the larger volute; H, the smaller volute; I, the flower; K, the abacus; L, the lip of the vase.

2587. Vitruvius is scanty in the information he gives on the Corinthian order, and what he says respecting it relates more to the origin of the capital and the like than to the proportions of the detail. He makes the capital only 1 diameter high, and then forms upon the plan a diagonal 2 diameters long, by means whereof the four faces are equal according to the length of the arc, whose curve will be the ninth part in length and its height the seventh part of the capital. He forms the order with a pedestal, with base and cornice, as Daniel Barbaro would have it. The whole height given to it in our measures is about 27 modules and 2 parts.

2588. Palladio uses the pedestal with its ordinary subdivisions, making it between a third and fourth part of the height of the column, including its base and capital. To the base he gives 1 module, the shaft of the column a little less than 8 diameters, and places twenty-four flutes upon it, which two thirds downwards are channelled, and on the other or lower third neatly fitted with convex pieces of segments of cylinders called *cablings*. He makes the capital 1 diameter and a sixth in height, giving it two tiers of leaves, caulicoli, and abacus. To the architrave, frieze, and cornice he assigns a little less than a fifth part of the column, including the base and capital. The whole height given to the order by this author is about 27 modules and 10 parts of our measures.

2589. Serlio makes his pedestal pretty nearly as the rest. To the base of the column he assigns half a diameter for the height, when that is about level with the eye, but when much above it he directs all the members to be increased in height accordingly, as where one order is placed above another, he recommends the number of parts to be diminished. To the shaft of the column he gives a little more than 7 diameters, and to the capital the same height as that given by Vitruvius, whom, nevertheless, he considers in error, or rather that some error has crept into the text, and that the abacus ought not to be included in the height. The height of the architrave, frieze, and cornice he makes a little less than a fourth part of the column, including its base and capital. The whole of the order, according to him, is 28 modules and a little more than 1 part of our measures.

2590. Scamozzi gives to the pedestal of this order the height of 3 diameters and one third, composing it with the usual parts of base, die, and cornice; to the base of the column the same height and mouldings as Palladio. To the shaft of the column he assigns the height of 8 diameters and one third, and diminishes it on each side an eighth part of its thickness at bottom. The capital is of the same height as that by Palladio. The architrave, frieze, and cornice he directs to be a little less than a fifth part of the height of the column. By our measures the whole height of his order is 30 modules and 20 parts.

Sect. VII.

THE COMPOSITE ORDER.

2591. The Composite order, as its name imports, is a compound of other orders, the Corinthian and Ionic, and was received into the regular number of orders by Vitruvius, who has described its proportions and character. Its capital consists, like the Corinthian, of two ranges of acanthus leaves distributed over the surface of a vase, but instead of the stalks or branches, the shoots appear small and as though flowering, adhering to the vase and rounding with the capital towards its middle. A fillet terminates the vase upwards, and over the fillet an astragal is placed, from which the volutes roll themselves to meet the tops of the upper tier of leaves, on which they seem to rest. A large acanthus leaf is bent above the volutes, for the apparent purpose of sustaining the corner of the abacus. which is dissimilar to that of the Corinthian order, inasmuch as the flower is not supported by a stalk seemingly fixed on the middle of each face of the abacus. The principal examples of

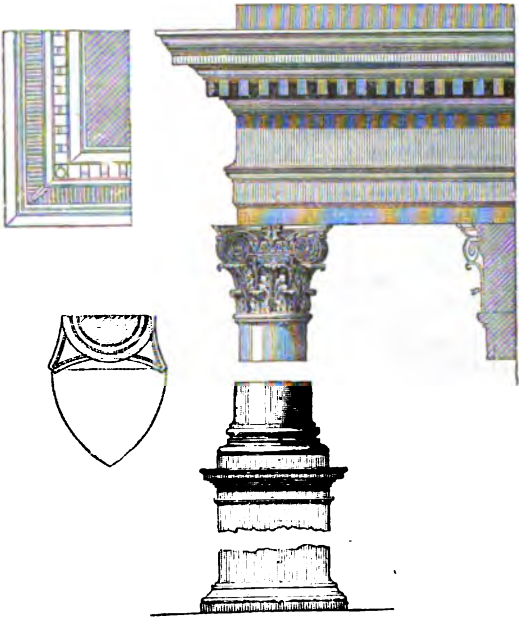

Fig. 891.

the order are at Rome, in the temple of Bacchus, the arches of Septimius Severus, of the Goldsmiths, and of Titus; also in the baths of Dioclesian.

2592. *Fig.* 891. (see preceding page) is a representation of Vignola's profile of the order. Its measures are subjoined in the following table: —

Members composing the Order.		Heights in Parts of a Module.	Projections from Axis in Parts of a Module.
	ENTABLATURE.		
A, Cornice, 36 parts.	Fillet of cornice	1½	51
	Cyma recta	5	51
	Fillet	1	46
	Cyma reversa	2	45½
	Bead	1	43¾
	Corona	5	43
	Cyma under the corona	1½	41
	Fillet	1	33
	Cyma reversa	4	32½
	Fillet of the dentils	½	28
	Dentils	7½	29
	Fillet	1	23
	Ovolo	5	22
B, Frieze, 27 parts.	Bead	1	17
	Fillet	½	16¼
	Congé	¾	15
	Upright face	17¼	15
	Apophyge	7	22
C, Architrave, 27 parts.	Fillet	1	22
	Cavetto	2	20½
	Ovolo	3	20
	Bead	1	17¾
	First fascia	10	17
	Cyma reversa	2	16⅔
	Second fascia	8	15
	COLUMN.		
Capital, 42 parts.	Echinus and fillet	2	20⅔
	Lower member of abacus	4	diagonally 32¼
	Volute	12	diagonally 30⅔
	Bend of upper leaves	3	24
	Upper leaves	9	22½
	Bend of lower leaves	3	20⅔
	Lower leaves	9	19⅓
Column, 16 mod. 12 parts.	Astragal	2	17½
	Fillet	1	16½
	Congé	2	15½
	Shaft Above	- -	15
		16 mod. 12 parts.	
	Shaft Below	- -	18
	Apophyge	2	20
	Fillet	1½	20
E, Base of column, 18 parts.	Congé	2	20
	Fillet	1½	20
	Torus	3	22
	Fillet	¼	20½
	Scotia	1½	20
	Fillet	¼	21½
	Bead	½	21¾
	Fillet	¼	21½
	Scotia	2	20⅔
	Fillet	¼	23
	Torus	4	25
	Plinth	6	25

Members composing the Order.		Heights in Parts of a Module.	Projections from Axis in Parts of a Module.
Pedestal.			
F, Cornice, 14 parts.	Fillet	½	33
	Cyma reversa	1½	32¾
	Corona	3	31½
	Cyma recta	1½	28½
	Fillet	½	26¼
	Cavetto	1	25¼
	Frieze	5	25
	Bead	1	27
Die, 94 parts.	Fillet	1	27¼
	Congé	1¼	25
	Die	88¾	25
	Apophyge	2	27
	Fillet	1	27
G, Base, 12 parts.	Bead	1	27¾
	Inverted cyma reversa	3	30¼
	Fillet	1	31¼
	Torus	3	33
	Plinth	4	33

2593. The flutes in this order are separated by a fillet between them, and are, when used, twenty-four in number.

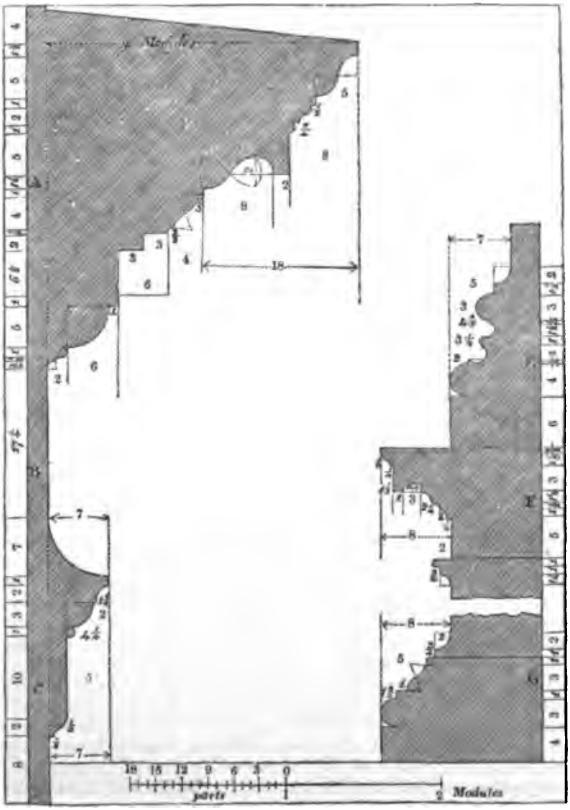

Fig. 902.

2594. *Fig.* 892. (see preceding page) shows the parts of the entablature, base, and pedestal to a larger scale, and *fig.* 893. gives, similarly, a more intelligible, because larger, representation of the mode of setting up the capital, which, as we have already observed, has only eight volutes. In this figure A is the plan, as viewed frontwise; B, that of the capital, viewed diagonally; C, the vase or body of the capital; D, the first tier of leaves; E, the second tier of the same; F, the volutes; G, the flower; H, the abacus.

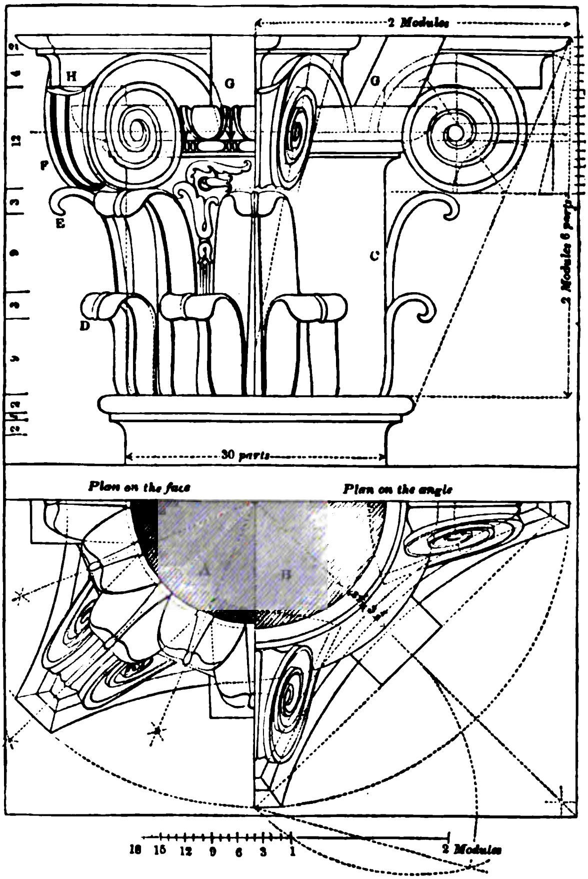

Fig. 893.

2595. Vitruvius has not given any instructions on this order; we are therefore obliged to begin our parallel, as in the other orders, with —

2596. Palladio, whose examples of it are light and much decorated. To the pedestal's height this master assigns 3 diameters and three eighths of the column, adding to it a lower plinth of the height of half a diameter. He makes the base of the column half a diameter in height, and assigns to the shaft 8 diameters and a little more than one fourth, and cuts on it twenty-four flutes. The height of this capital is 1 diameter and a sixth, his volutes being very similar to those he prescribes for his Ionic. The architrave, frieze, and cornice he makes a little less than a fifth part of the height of the column. The whole height of his profile in our measures is 30 modules and 12 parts.

2597. Serlio seems to have founded his profile of this order upon the example in the Coliseum at Rome. He makes the height of the pedestal a little less than 4 diameters of the column. To the shaft of the column he assigns 8 diameters and a half. To the height of the capital he gives 1 diameter, differing therein from his profile of the Corinthian order in the disposition of the volutes and leaves. His entablature, which is a little less in height than one fourth of the column, he divides into three equal parts for the architrave, frieze, and cornice. The total height of his profile in our measures is 32 modules and 9 parts, being much higher than that of Palladio.

2598. Scamozzi's profile greatly resembles that of Palladio. His pedestal is 3 diameters, and the base of his column half a diameter in height. The shaft of his column, without base or capital, is 8 diameters and one twelfth high, and the capital 1 diameter and a sixth. The entablature is one fifth part of the column in height, and the whole of the profile in our measures is nearly 29 modules and 7 parts.

Sect. VIII.

PEDESTALS.

2599. We think it necessary to devote a small portion of this chapter to the consideration of pedestals, on account of the great difference which exists in the examples of the orders, and this we shall place in a tabular form, previous to the general remarks it will be necessary to make.

Table showing the Height of Pedestals in ancient and modern Works.

		Plinth in Minutes.	Mouldings above Plinth in Minutes.	Die in Minutes.	Cornice in Minutes.	Total Height in Minutes.
Doric	Palladio - -	26	14	80	20	140
	Scamozzi - -	30	15	68 4/7	22½	136 1/14
Ionic	Temple of Fortuna Virilis - -	44	19¾	93¾	23¼	180¾
	Coliseum - -	33¼	9½	81⅜	17	141⅛
	Palladio - -	28⅔	14⅓	97¾	21½	162¼
	Scamozzi - -	30	15	82½	22½	150
Corinthian	Arch of Constantine -	17½	29	153	29½	228
	Coliseum - -	23	11½	78	19¼	131¾
	Palladio - -	23½	14½	93	19	150
	Scamozzi - -	30	15	132½	22½	200
Composite	Arch of Titus -	55	30	141	29	255
	Arch of the Goldsmiths - -	46	25¼	144½	25¼	241
	Arch of Septimius Severus • -	30	30⅝	140½	29⅝	182⅛
	Palladio - -	33	17	133	17	200
	Scamozzi - -	30	15	112½	22½	180

2600. The minutes used in the above table are each equal to one sixtieth of the diameter of the shaft.

2601. Whether the pedestal is to be considered a component part of an order is of little importance. There are so many cases that arise in designing a building, in which it cannot be dispensed with, that we think it useful to connect it with the column and entablature, and have consequently done so in the examples already given of the several orders. Vitruvius, in the Doric, Corinthian, and Tuscan orders, makes no mention of pedestals, and in the Ionic order he seems to consider them rather as a necessary part in the construction of a temple than as belonging to the order itself.

2602. A pedestal consists properly of three parts, the base, the die, and the cornice. "Some authors," says Chambers, "are very averse to pedestals, and compare a column raised on a pedestal to a man mounted on stilts, imagining they were first introduced merely through necessity, and for want of columns of a sufficient length. "It is indeed true," he continues, "that the ancients often made use of artifices to lengthen their columns, as appears by some that are in the baptistery of Constantine at Rome; the shafts of which, being too short for the building, were lengthened and joined to their bases by an undulated sweep, adorned with acanthus leaves; and the same expedient has been made use of in some fragments which were discovered a few years ago at Nismes, contiguous to the temple of Diana. Nevertheless, it doth not seem proper to comprehend pedestals in the number of these artifices, since there are many occasions on which they are evidently necessary, and some in which the order, were it not so raised, would lose much of its beautiful appearance. Thus, within our churches, if the columns supporting the vault were placed immediately on the ground, the seats would hide their bases and a good part of their shafts; and in the theatres of the ancients, if the columns of the scene had been placed immediately on the stage, the actors would have hid a considerable part of them from the audience; for which reason it was usual to raise them on very high pedestals, as was likewise necessary in their triumphal arches; and in most of their temples the columns were placed on a basement or continued pedestal (*stylobata*), that so the whole might be exposed to view, notwithstanding the crowds of people with which these places were frequently surrounded. And the same reason will authorise the same practice in our churches, theatres, courts of justice, or other public buildings where crowds frequently assemble. In interior decorations, where, generally speaking, grandeur of style is not to be aimed at, a pedestal diminishes the parts of the order, which otherwise might appear too clumsy; and has the farther advantage of placing the columns in a more favourable view, by raising their base nearer to the level of the spectator's eye. And in a second order of arcades there is no avoiding pedestals, as without them it is impossible to give the arches any tolerable proportion. Sometimes, too, the situation makes it necessary to employ pedestals, an instance of which there is in the Luxembourg at Paris; where, the body of the building standing on higher ground than the wings, the architect was obliged to raise the first order of the wings on a pedestal, to bring it upon a level with that of the body or *corps de logis* of the building, which stands immediately on the pavement."

2603. The dies of pedestals are occasionally decorated with tablets or with sunk panels whose margins are moulded; but, generally speaking, such practices are to be avoided. In very large pedestals the surface may be thus broken, as in single monumental columns, which, at best, are but paltry substitutes for originality. Habit has reconciled us to view with pleasure the Trajan and Antonine columns, the monument of London, and the column of Napoleon in the Place Vendôme at Paris, in each of which the pedestals are ornamented in some way or other, so as to tell in some measure the story of the person in whose honour they were erected, or, as in the basso-relievo of the London column, the event which it records. But care must be taken when inscriptions are used to preserve a rigid adherence to truth, and not to perpetuate a lie, as was the case in the monument just named, against a most worthy portion of the people of the British empire.

2604. As respects the employment of pedestals, we should advise the student, except under very extraordinary circumstances, to avoid the use of them under columns which are placed at a distance from the main walls of an edifice, as, for example, in porches peristyles, or porticoes, — a vice most prevalent in the Elizabethan architecture, or rather the cinque-cento period, which the people of this day are attempting with all its absurdities to revive. Here we must again quote our author, Sir William Chambers, whose excellent work we have used above, and on which we shall continue to draw largely. "With regard," he says, "to the application of pedestals, it must be observed, that when columns are entirely detached, and at a considerable distance from the wall, as when they are employed to form porches, peristyles, or porticoes, they should never be placed on detached pedestals, as they are in some of Scamozzi's designs, in the temple of Scisi (Assisi) mentioned by Palladio, and at Lord Archer's house, now Lowe's hotel, in Covent Garden; for then they indeed may be compared to men mounted on stilts, as they have a very weak and tottering appearance. In compositions of this kind, it is generally best to place the columns immediately on the pavement, which may be either raised on a continued solid basement, or be ascended to by a flight of fronting steps, as at St. Paul's, and at St. George's Bloomsbury; but if it be absolutely necessary to have a fence in the intercolumniations, as in the case of bridges or other buildings on the water, or in a second order, the columns may then, in very large buildings, be raised on a continued plinth, as in the upper order of the western porch of St. Paul's, which in such case will be sufficiently high: and in smaller buildings, wherever it may not be convenient or proper to place the balustrade between the shafts, the columns may be placed on a continued pedestal, as they are in Palladio's designs for Signor Cornaro's house at Piombino, and at the villa Arsieri, near Vicenza, another beautiful building of the same master." The same author continues: "The base and cornice of these pedestals must run in a straight line on the outside throughout, but the dies are made no broader than the plinths of the columns, the intervals between them being filled with balusters, which is both really and apparently lighter than if the whole pedestal were a continued solid." The author quoted then proceeds to caution the student against the employment of triangular, circular, and polygonal pedestals, and such as are swelled and have their die in the form of a baluster, or are surrounded by cinctures.

These extravagances were rife in the age of Louis XV., but notwithstanding the zeal of the jobbing upholsterers and decorators of the present day, who are the curse of all architectural art, we hope they will never be permanently revived in this country, though their introduction has already proceeded to a considerable extent.

Sect. IX.

INTERCOLUMNIATIONS.

2605. An intercolumniation is the clear distance between two columns measured at the lower diameter of their shafts. This distance must depend principally on the order employed: in the Tuscan, for example, the nature of its composition allows a greater width between columns than would be admissible in the Corinthian order, independent of what has already been stated in Sect. II. (2524, *et seq.*) in respect of supports and loading; and this because of the enrichments of the several orders requiring that they should take their departures (to use a phrase borrowed from another science) from the axes of their respective columns. The ancient names (which are still preserved) of the different intercolumniations are described by Vitruvius in his second and fourth books. They are — the *pycnostyle*, wherein the space between the columns is 1 diameter and a half, as its etymology from *πυκνος* and *στυλος* imports (thick in columns), an intercolumniation used only in the Ionic and Corinthian orders; the *systyle* (*συστυλος*, with columns a little more apart), wherein the interval between the columns is a little greater; the *eustyle* (*ευστυλος*, or well-contrived interval), wherein the intercolumniation is of 2 diameters and a quarter; the *diastyle* (*διαστυλος*, with a more extended interval between the columns), having an intercolumniation of 3 diameters; and the *aræostyle* (*αραιοστυλος*, with few columns), wherein the interval is 4 diameters. In the Doric order the triglyphs necessarily regulate the intercolumniations, inasmuch as the triglyph should fall over the axis of the column; hence the intercolumniations in this order are either systyle monotriglyph (that is, with a single triglyph in the intercolumniation), or 1½ diameter; diastyle, or of 2¾ diameters; or aræostyle, which will make the interval 4 diameters, as will be immediately understood on reference to *fig.* 894.; wherein A is the sysytle monotriglyph intercolumniation of 3 modules; B, that of the diastyle, or 6 modules; and C, the aræostyle, or of 8 modules. The intercolumniation marked D serves for the application of coupled columns, wherein the rule seems necessarily to be that the space between the columns may be increased, so that the requisite number of supports according to the order and intercolumniation is preserved.

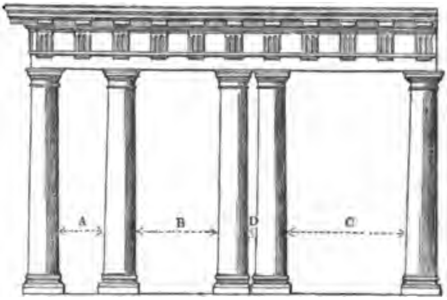

Fig. 894.

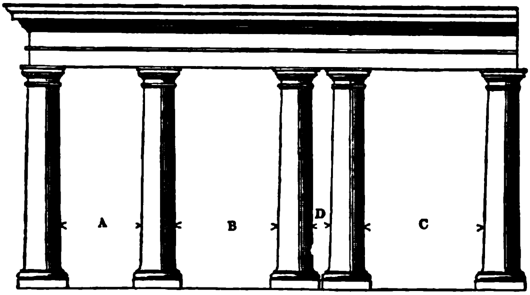

Fig. 895.

2606. The intervals of the Tuscan order are indicated in *fig.* 895., wherein A shows the intercolumniation called eustyle of 4½ modules; B, the diastyle of 6 modules; and C, the aræostyle of 8. D, of 1 module, is the space of coupled columns.

The intercolumniations in this order are scarcely susceptible of rules other than those we have indicated in our previous discussion on the orders generally in Sect. II. (2523, *et seq.*), wherein we have entered on the subject at such length that we refrain from saying more in this place. We may, however, observe, that the application of the principles there mentioned are so intimately connected with this section, that the separation of one from the other would destroy all our scheme for keeping the student in the right path. Hereafter the principles in question will be applied to and tested on arcades.

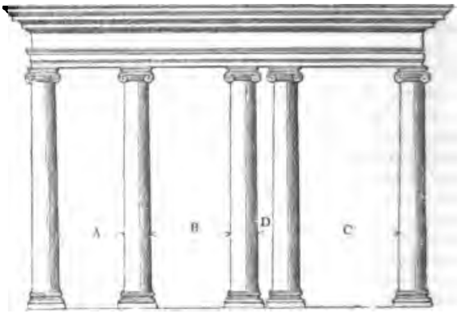

Fig. 896.

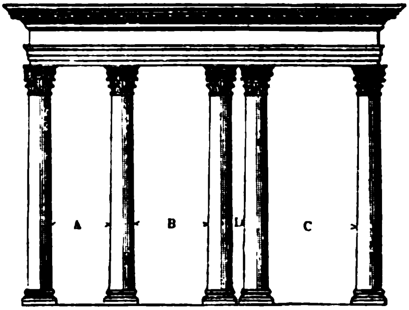

Fig. 897.

2607. In *fig.* 896., of Ionic intercolumniations, A is the eustyle arrangement; B, that of the diastyle; C, that of the aræostyle; and D, that of coupled columns.

2608. *Fig.* 897. is a similar application of the intercolumniations to the Corinthian order, wherein also A exhibits the eustyle; B, the diastyle; and C, the aræostyle intervals: D also showing the space used of 1 module for coupled columns.

2609. Sir William Chambers, for whose observations we have much respect, — and, indeed, to whose valuable labours we acknowledge ourselves much indebted, — seems to have had a distant glimpse of the doctrine of equal weights and supports, but knew not exactly how to justify his notions on the subject. He therefore avoids the main question by attributing the pycnostyle intercolumniation rather to necessity than choice; observing, that "as the architraves were composed of single stones or blocks of marble, extending from the axis of one column to that of another, it would have been difficult to find blocks of a sufficient length for diastyle intervals in large buildings." But this is a reason altogether unsatisfactory, inasmuch as we know that they were sufficiently masters of masonry to have conquered any such difficulty. We are much more inclined to agree with him when he says (always, however, reverting to the principle of equal supports and weights), "With regard to the aræostyle and Tuscan intercolumniations, they are by much too wide either for beauty or strength, and can only be used in structures where the architraves are of wood, and where convenience and economy take place of all other considerations: nor is the diastyle sufficiently solid in large compositions." These considerations, however, may be always safely referred to the doctrines laid down in Section II. of this Chapter, already alluded to; and, indeed, that reference is justified by the instructions of Vitruvius in the second chapter of his third book, wherein he directs that the thickness of the column should be augmented in an enlarged intercolumniation: as, for example, supposing the diameter of a column in the pycnostyle species to be taken one tenth of the height, it should in an aræostyle be one eighth; arguing, that if in an aræostyle the thickness of the columns exceed not a ninth or tenth part of their height, they appear too slender, and in the pycnostyle species the column at one eighth of its height is clumsy and unpleasant in appearance. Upon this passage Chambers observes, "that the intention of Vitruvius was good, but the means by which he attempts to compass it insufficient. His design was to strengthen the supports in proportion as the intervals between them were enlarged; yet according to the method proposed by him this cannot be effected, since one necessary consequence of augmenting the diameter of the column is enlarging the intercolumniation proportionably. Palladio and Scamozzi have however admitted this precept as literally just, and by their manner of applying it have been guilty of very considerable absurdity." We are not at all inclined to admit the truth of the opinion of Chambers; for, again reverting to the doctrine of the supports and loading, which was unknown to him, it is to be remembered that increase in the space of the intercolumniation immediately involves increase of weight in the load or entablature, and therefore seems to demand increase of diameter to the supports. Palladio and Scamozzi were not therefore guilty of the absurdity laid to their charge.

2610. Among the other reasons for our adopting the practice of Vignola is that he has observed so much uniformity in his intercolumniations, except of the Doric order, wherein the triglyphs prevent it, aware as we are that the practice has by many able writers been much condemned. Chambers even says that his practice in this respect is "preferable to any other, as it answers perfectly the intention of Vitruvius, preserves the character of each order, and maintains in all of them an equal degree of real solidity."

2611. With the exception of the Doric order, wherein the most perfect arrangement of the detail results from the interval produced by the ditriglyph, there can be no doubt that, abstractedly considered, the diastyle and eustyle intercolumniations are very convenient in use, and may be employed on most occasions, except, as just mentioned, in the Doric order.

2612. In setting out the intervals between columns especial care must be taken that the centres of modillions, dentils, and other ornaments in the entablature fall over the axes of the columns. It is on this account that Vignola gives about two diameters and a third to the intervals in all the orders except the Doric, instead of two diameters and a quarter, as required by Vitruvius; an alteration which removes the difficulty and greatly simplifies the rules.

2613. Cases from many circumstances often occur where greater intercolumniations than the eustyle and diastyle are too narrow for use, and the moderns, headed by Perrault, have adopted an interval which that master has called aræosystyle. This disposition is obtained without infringing on the law of weights and supports, to which we have already so often alluded. In it the columns are *coupled*, as shown in the preceding figures, the interval being formed by swo systyle intercolumniations, the column separating them being, as Chambers observes, "approached towards one of those at the extremities, sufficient room being only left between them for the projection of the capitals, so that the great space is 3½ diameters wide, and the small one only half a diameter." One of the finest examples of this practice is to be seen in the façade of the Louvre, (see *fig.* 176.) which in many respects must be considered as the finest of modern buildings. The objections of Blondel to the practice are not without some weight, but the principal one is the extra expense incurred by it; for certain it is that it requires nearly double the number of columns wanted in the diastyle, besides which it cannot be denied that it causes considerable irregularities in the entablatures of the Doric, Corinthian, and Composite orders, which, however, are not apparent in the other two. It is, nevertheless, so useful in cases of difficulty which constantly arise, that we should be sorry to exclude the practice altogether, though we cannot recommend it for unlimited adoption.

2614. A great many expedients have been employed to obviate the irregularity of the modillions in the Corinthian and Composite orders, arising from the grouping of columns. We, on this head, agree with Chambers, whose instructions we subjoin in his own words: "The simplest and best manner of proceeding is to observe a regular distribution in the entablature, without any alteration in its measures, beginning at the two extremities of the building, by which method the modillions will answer to the middle of every other column, and be so near the middle of the intermediate ones, that the difference will not easily be perceivable. The only inconvenience arising from this practice is, that the three central intercolumniations of the composition will be broader by one third of a module than is necessary for eleven modillions: but this is a very trifling difference, easily divided and rendered imperceptible if the extent be anything considerable." In the Doric order, the grouping of columns is not so easily managed, and therein our author recommends the expedient employed by Palladio, in the Palazzo Chiericato, and in the Basilica at Vicenza. In the last-named, the coupled columns are only 21 minutes apart, thus making the space between the axes 2 modules and 21 minutes, that is, 6 minutes beyond the breadth of a regular metope, and 2 half-triglyphs. To conceal the excess, the triglyphs are 31 minutes broad, and their centres are carried 1 minute within the axis of the column, and the metope is 3 minutes broader than the others. These small differences are not perceptible without a very critical and close examination of the distribution. In this arrangement the attic base of Palladio should be employed, because of its small projection, and the larger intercolumniation must be aræostyle.

2615. Intercolumniations should be preserved of equal width in all peristyles, galleries, porticoes, and the like; but in loggias or porches, the middle interval may be wider than the others by a triglyph, a modillion or two, and a few dentils, that is, if there be no coupled columns at the angles nor groupings with pilasters, in which cases all the other intervals should be of the same dimensions. It has been observed by Blondel, that on occasions where several rows of columns are used, as, for instance, in the curved colonnades of the piazza of St. Peter's, the columns ought as much as possible to be in straight lines, because otherwise the arrangement can only be understood by viewing it from the centre of the figure employed. The observation is well worth the student's consideration, for the resulting effect of a departure from this rule, as Chambers has properly observed, is "nothing but confusion to the spectator's eye from every point of view." The same author condemns, and with justice, though in a smaller degree, the use of "engaged pilasters or half columns placed behind the detached columns of single, circular, oval, or polygonal peristyles, as may be seen in those of Burlington House. Wherefore," he says, "in buildings of that kind, it will perhaps be best to decorate the back wall of the peristyle with windows or niches only." We can hardly suppose it here necessary to caution the student against the use of intercolumniations without reference to the absolute size of them: they must not be less than three feet even in small buildings, because, as Sir William Chambers seriously says, "there is not room for a *fat* person to pass between them."

2616. Before leaving the subject which has furnished the preceding remarks on intercolumniations, we most earnestly recommend to the student the re-perusal of Section II. of this Book. The intervals between the columns have, in this section, been considered more with regard to the laws resulting from the distribution of the subordinate parts, than with relation to the weights and supports, which seem to have regulated the ancient practice: but this distribution should not prevent the application generally of the principle, which may without difficulty, as we know from our own experience, be so brought to bear upon it as to produce the most satisfactory results. We may be perhaps accused of bringing a fine art under mechanical laws, and reducing refinement to rules. We regret that we cannot bind the professor by more stringent regulations. It is certain that, having in this respect carried the point to its utmost limit, there will still be ample opportunity left for him to snatch that grace, beyond the reach of art, with the neglect whereof the critics are wont so much to taunt the artist in every branch.

Sect. X.

ARCADES AND ARCHES.

2617. An arcade, or series of arches, is perhaps one of the most beautiful objects attached to the buildings of a city which architecture affords. The utility, moreover, of arcades in some climates, for shelter from rain and heat, is obvious; but in this dark climate, the inconveniences resulting from the obstruction to light which they offer, seems to preclude their use in the cities of England. About public buildings, however, where the want of light is of no importance to the lower story, as in theatres, courts of law, churches, and places of public amusement, and in large country seats, their introduction is often the source of great beauty, when fitly placed.

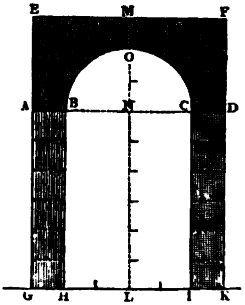

Fig. 898.

2618. In a previous section (2524.) we have spoken of Lebrun's theory of an equality between the weights and supports in decorative architecture: we shall here return to the subject, as applied to arcades, though the analogy is not, perhaps, strictly in point, because of the dissimilarity of an arch to a straight lintel. In *fig.* 898. the hatched part AEMFDCOB is the load, and ABGH, CDIK the supports. The line GK is divided into six parts, which serve as a scale to the diagram, the opening HI being four of them, the height BH six, NO two, and OM one. From the exact quadrature of the circle being unknown, it is impossible to measure with strict accuracy the surface BOC, which is necessary for finding by subtraction the surface AEMFDCOB; but using the common method, we have

$$AD \times AE - \frac{BC^2 \times \cdot 7854}{2} = \text{ to that surface; or, in figures,}$$

$$6 \times 3 - \frac{4 \times 4 \times \cdot 7854}{2} = 11 \cdot 72.$$

Now the suports will be IK × IC × 2 (the two piers) = the piers; or, in figures,

$$1 \times 6 \times 2 \qquad = 12 \cdot 00.$$

That is, in the diagram the load is very nearly equal to the supports, and would have been found quite so, if we could have more accurately measured the circle, or had with greater nicety constructed it. But we have here, where strict mathematical precision is not our object, a sufficient ground for the observations which follow, and which, if not founded on something more than speculation, form a series of very singular accidents. We have chosen to illustrate the matter by an investigation of the examples of arcades by Vignola, because we have thought his orders and arcades of a higher finish than those of any other master; but testing the hypothesis, which we intend to carry out by examples from Palladio, Scamozzi, and the other great masters of our art, not contemplated by Lebrun, the small differences, instead of throwing a doubt upon, seem to confirm it.

2619. In *fig.* 898. we will now carry, therefore, the consideration of the weights and supports a step further than Lebrun, by comparing them with the void space they surround, that is, the opening HBOCI; and here we have the rectangle HBCI = HB × HI, that is, 6 × 4 = 24, and the semicircle BOC equal, as above, to $\frac{4 \times 4 \times \cdot 7854}{2} = 6 \cdot 28$. Then $24 + 6 \cdot 28 = 30 \cdot 28$ is the area of the whole void, and the weight and support being $11 \cdot 72 +$

12 = 23·72, are a little more than two thirds the areas of the whole void; a proportion which, if we are to rely on the approval of ages in its application, will be found near the limits of what is beautiful.

2620. We shall now refer to the examples of Vignola alluded to; but to save the repetition of figures in their numbers, as referred to, each case is supposed in what immediately follows as unconnected with the entablatures which they exhibit, it being our intention to take those into separate consideration.

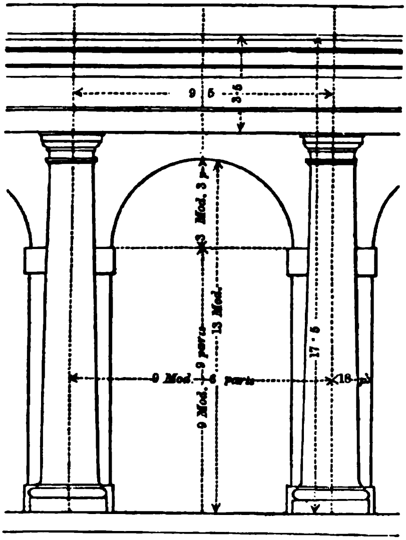

Fig. 899.

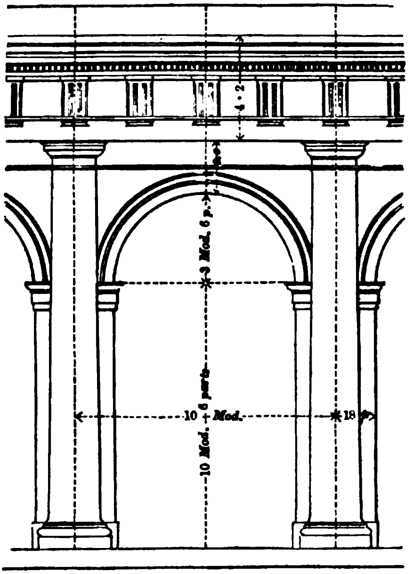

Fig. 900.

2621. Suppose the Tuscan example (*fig.* 899.) without an entablature, we have the

Supports, 9·75 × 3 = 29·25
The whole of rectangle above them, 4·25 × 9·5 = 40·375
Less semi-arch, $\frac{6·5 \times 6·5 \times ·7854}{2} = 16·6$
——— 23·775
——— 53·025 solid parts.

The area of the void is $16·6 + \overline{9·75 \times 6·5} = 79·97$, whereof 53·025, the portion of solid parts, is not widely different from two thirds.

In Vignola's Doric example, (*fig.* 900.), again without the entablature, we have

Supports, 10·5 × 3 = 31·50
The whole rectangle above them, 5·5 × 10·0 = 55·00
Less semi-arch, $\frac{7 \times 7 \times ·7854}{2} = 19·24$
——— 35·76
——— 67·26 solid parts.

The area of the void is $19·24 + \overline{10·5 \times 7} = 92·74$, whereof 67·26, the portion of solid parts, is not much different from two-thirds.

In the Ionic example (*fig.* 901.), still without considering the entablature, the following will result:—

Supports, 12·64 × 2·66 = 33·61
The whole rectangle above them, 10·88 × 5·2 = 56·57
Less semi-arch, $\frac{6·4 \times 6·4 \times ·7854}{2} = 16·08$
——— 40·49
——— 74·10 solid parts.

The area of the void is $16·08 + \overline{12·64 \times 7·1} = 105·82$, whereof 74·10, the portion of solid parts, differs little in amount from two thirds of the void.

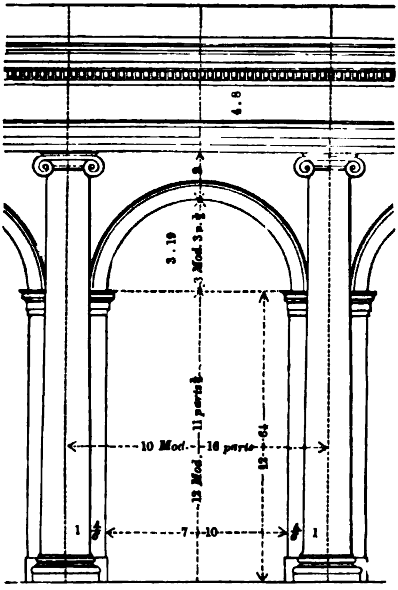

Fig. 901.

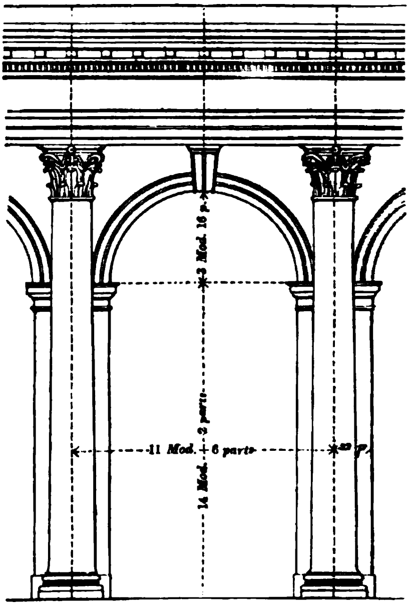

Fig. 902.

In the Corinthian example (*fig.* 902.), not taking into consideration the entablature, the following is the result: —

Supports, 14·11 × 3·55 = 50·09

The whole rectangle above them, 11·33 × 5·88 = 66·62

Less semi-arch, $\frac{7{\cdot}76 \times 7{\cdot}76 \times {\cdot}7854}{2}$ = 23·65

= 32·97

83·06 solid parts.

The area of the void is 23·65 + $\overline{14{\cdot}111 \times 7{\cdot}76}$ = 133·15, whereof 83·06, the portion of solid parts, is somewhat less than two thirds of the void.

2622. The result which flows from the above examination seems to be that, without respect to the entablature, the ratio of the solid part to that of the void is about ·666. Bearing this in mind, we shall next investigate the ratio of the supports and weights, considering the entablature above the arcade as a part of the composition; and still following Vignola, whose examples, as we have above stated, do not so much differ from those of other masters as to make it necessary to examine those of each, we will begin with that architect's Tuscan arcade, without pedestals, exhibited in *fig.* 899. on the preceding page. In this example, from centre to centre of pier,

The whole area, in round numbers, 17·5 × 9·5 - - - = 166·2

Area of semi-arch, $\frac{6{\cdot}5 \times 6{\cdot}5 \times {\cdot}7854}{2}$ - - = 16·6

Rectangle under it, 9·75 × 6·5 - - = 63·3

Total void, therefore, = 79·9

86·3

Entablature, 9·5 × 3·5 - - - - - - = 33·2

Leaves for the supporting parts - - - - - 53·1

In this example, therefore, the supporting parts are 53, those supported 33, and the voids 79. The ratio between the solid and void parts = ·9, and the ratio of the supports to the weights is $\frac{33}{53}$ = ·62.

The distance between the axes of the columns is 9 modules and 6 parts; the height of the semi-arch, 3 modules and 3 parts; and between the crown of it and the under side of the architrave is 1 module; the whole height, including entablature, being 17 modules and a half.

2623. Following the same general method, we submit the Doric arcade (*fig.* 900.) without pedestal. Measuring, as before, from centre to centre of piers,

The whole area, in round numbers, 20·2 × 10 - - - =202·0
Area of semi-arch $\frac{7 \times 7 \times \cdot 7854}{2}$ - - - =19·2
Rectangle under it, 10·5 × 7 - - =73·5
Total void, therefore, = 92·7
109·3
Entablature, 10 × 4·2 - - - - - - 42·0
Leaves for the supporting parts - - - - - 67·3

In this example, therefore, the supporting parts are 67, those supported 42, and the voids 92. The ratio between the solid and void parts is ·85, and the ratio of the supports to the weights is $\frac{42}{67}$= ·63.

The distance between the axes of the columns is 10 modules, the height of the semi-arch is 3 modules and 6 parts, and between the crown of it and the underside of the architrave is 2 modules; the whole height, including the entablature, being 20 modules 3½ parts.

2624. The Ionic arcade, without pedestal, is shown in *fig.* 901. The measurements, as above, from centre to centre of pier,

The whole area, 22·64 × 10·88 in round numbers - - - =246·3
Area of semi-arch, $\frac{6 \cdot 4 \times 6 \cdot 4 \times \cdot 7854}{2}$ - - =16 1
Rectangle under it, 12·64 × 7·1 - - =89·7
Total void, therefore, =105·8
140·5
Entablature, 10·88 × 4·8 - - - - - - 52·2
Leaves for the supporting parts - - - - - 88·3

Hence, in the example, the supporting parts are 88, those supported 52, and the voids 105; so that the ratio of the voids to the solids, in this order, is ·8, and the ratio of the supports to the weights does not materially differ from the other orders, being $\frac{52}{88}$= ·6.

The distance between the axes of the columns is 10 modules 16 parts, the height of the semi-arch is 3½ modules 3 parts, and between the crown of it and the under side of the architrave is 2 modules; the whole height, including the entablature, being 22 modules 13½ parts.

2625. *Fig.* 902. represents the Corinthian arcade without pedestal. The measurement, as before, is from centre to centre of pier.

The whole area, 25·2 × 11·33, in round numbers - - = 288·5
Area of semi-arch, $\frac{7 \cdot 76 \times 7 \cdot 76 \times \cdot 7854}{2}$ = 23·6
Rectangle under it, 14·11 × 7·76 = 109·5
Total voids, therefore, = 133·1
155·4
Entablature, 10·36 × 5·6 - - - - - - 58·0
Leaves for the supporting parts - - - - - 97·4

In the Corinthian example, therefore, the supporting parts are 97, those supported 58, and the voids 133. The ratio between the solid and void parts = ·8, and the ratio of the supports to the weights $\frac{58}{97}$= ·59. The distance between the axes of the columns is 11 modules and 6 parts, the height of the semi-arch is 3 modules 16 parts, and between the crown of it and the under side of the architrave is 2 modules 3½ parts; the whole height, including the entablature, being 25 modules 3½ parts.

2626. The laws laid down by Chambers for regulating arcades are as follow: — "The void or aperture of arches should never be much more in height nor much less than double their width; the breadth of the pier should seldom exceed two thirds, nor be less than one third of the width of the arch, according to the character of the composition, and the angular piers should be broader than the rest by one half, one third, or one fourth." . . . "The height of the impost should not be more than one seventh, nor need it ever be less than one ninth of the width of the aperture, and the archivolt must not be more than one eighth nor less than one tenth thereof. The breadth of the console or mask, which serves as a key to the arch, should at the bottom be equal to that of the archivolt, and its sides must be drawn from the centre of the arch. The length thereof ought not to be less than one and a half of its bottom breadth, nor more than double."

2627. The ratios that have been deduced by comparing the void and solid parts, if there be any reason in the considerations had, show that this law of making arches in arcades of the height of 2 diameters is not empirical, the following being the results of the use of the ratios in the arcade without, and that with pedestal, of which we shall presently treat. Thus in the

		Diameters.		Diameters.
Tuscan arcade without pedestal,	$\frac{13\cdot5 \text{ height}}{6\cdot5 \text{ width}}$	$=2\cdot0$;	with pedestals, $\frac{17\cdot5}{9\cdot5}$	$=1\cdot84$
Doric arcade without pedestal,	$\frac{14\cdot0}{7}$	$=2\cdot0$	— $\frac{20\cdot0}{10\cdot0}$	$=2\cdot00$
Ionic arcade without pedestal,	$\frac{15\cdot83}{7\cdot10}$	$=2\cdot2$	— $\frac{22\cdot0}{11\cdot0}$	$=2\cdot00$
Corinthian arcade without pedestal,	$\frac{18\cdot00}{7\cdot76}$	$=2\cdot3$	— $\frac{25\cdot0}{12\cdot0}$	$=2\cdot08$

2628. In the examples of the arcades with pedestals, we shall again repeat the process by which the results are obtained, first merely stating them in round numbers. *Fig.* 903. is a Tuscan arcade from Vignola's example, as will be the following ones. In this the whole area is 306, omitting fractions, the area of the void is 156, that of the entablature 50, and the supports 100. The ratio of the supported part (the entablature), therefore, is $\frac{50}{100}=\cdot5$, and the supports and weights are very nearly equal to the void. The height of the pedestal is almost 3 modules and 8 parts, the opening 9 modules 6 parts, and the width of the whole pier 4 modules and 3 parts.

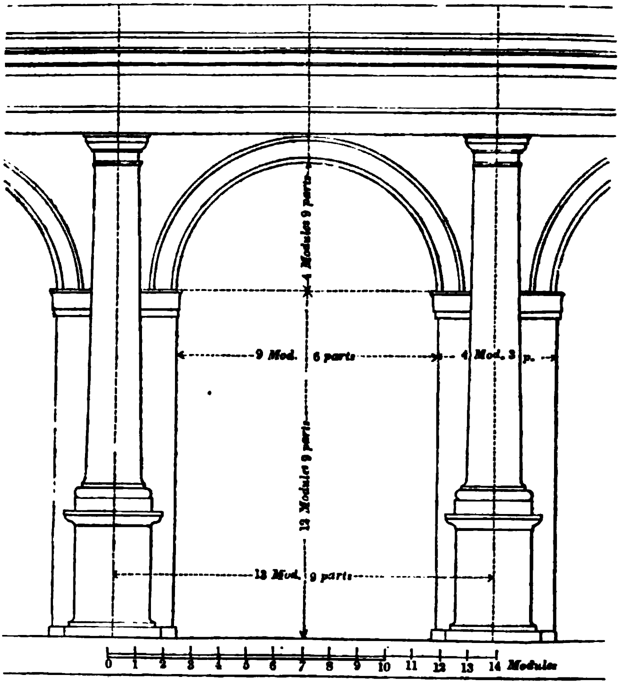

Fig. 903.

The detail of the above result is as follows: —

The whole area, $22\cdot30 \times 13\cdot75$ - - - - $=306\cdot62$

Area of semi-arch, $\frac{9\cdot5\times9\cdot5\times\cdot7854}{2} = 35\cdot43$

Below that, $12\cdot75 \times 9\cdot75$ - $=121\cdot12$

Total voids, therefore, $=156\cdot55$

$150\cdot07$

Entablature, $13\cdot75 \times 3\cdot66$ - - - - - $=50\cdot32$

Leaves for supporting parts - - - - $99\cdot75$

It will be seen that we have taken the numbers in the preceding paragraph without supplying strictly the decimal parts that arise from the multiplication and subtraction of the several portions compared. The coincidence of the hypothesis with the apparent law is no less remarkable in this example than it will be found in those that follow; and, sceptical as we at first were on the appearances which pointed to it, we cannot, after the examination here and hereafter given, do otherwise than express our conviction that, in carrying out the principles, no unpleasant combination can result.

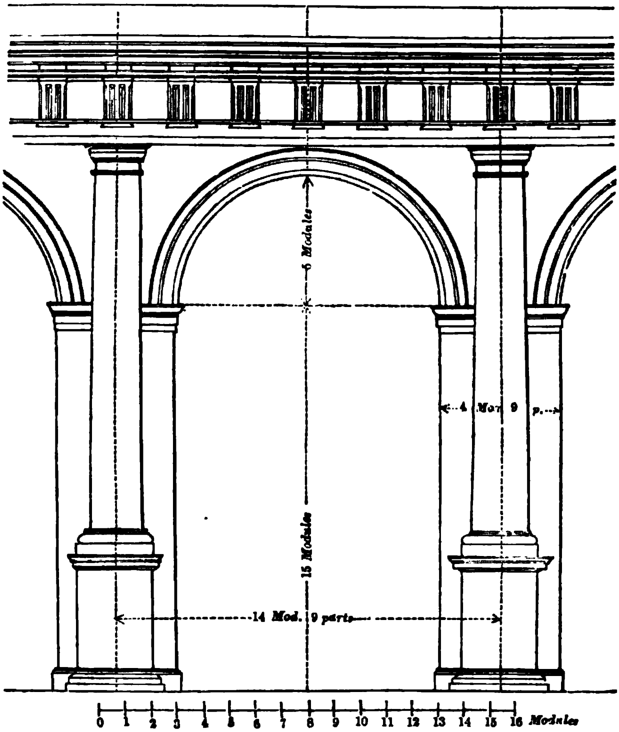

Fig. 904.

2629. *Fig.* 904. exhibits the Doric arcade, whose whole area from centre to centre of columns is 374. The area of the void is 189, that of the entablature 62, and of the supporting parts 112. The ratio of the entablature to the supports is therefore $\frac{62}{112}$ = ·55, and that of the supports and weights to the voids ·9. The height of the pedestal is almost 5 modules and 4 parts, the opening 10 modules, and the width of a pier 4 modules and 9 parts.

As in the preceding example, we think it will be useful to detail the process by which the general results stated have been arrived at. It is curious and interesting to observe the similarity between the cases. It is scarcely possible to believe that accident could have produced it. May not the freemasons of the middle ages have had some laws of this nature which guided their operations? But we will now proceed to the calculation.

The whole area, 25·4 × 14·75 - - - - =374·65

Area of semi-arch, $\frac{10{\cdot}0 \times 10{\cdot}0 \times {\cdot}7854}{2}$ = 39·27

Below that, 12·75 × 9·75 - =150·00

Total voids, therefore, - =189·27

185·38

Entablature, 14·75 × 4·25 - - - - - = 62·68

Leaves for supporting parts - - - - - 122·70

Herein, as before, the general result in the preceding paragraph has been given in round numbers, that the mind of the reader may not be distracted from the general proportions. The detail again corroborates the hypothesis, as in the preceding subsection was predicated, and the further we proceed, as will be presently seen, its truth becomes more manifest.

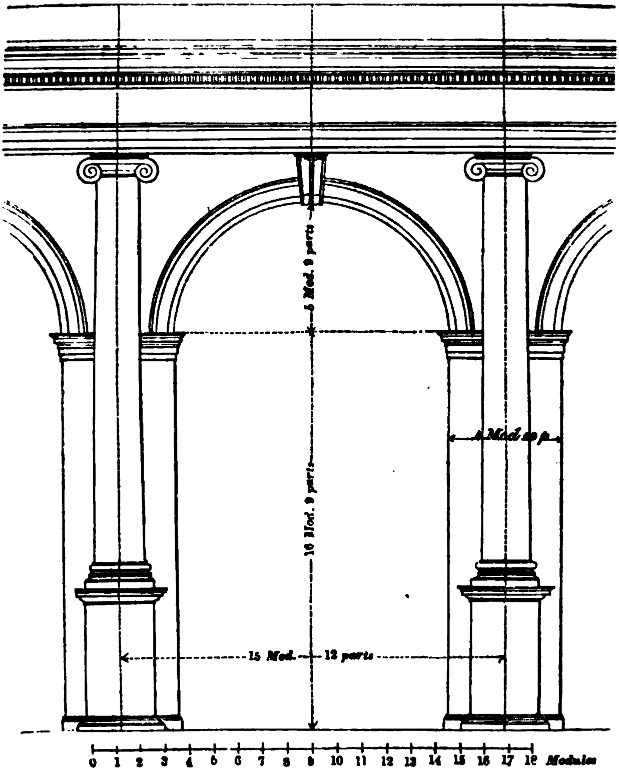

Fig. 905.

2630. The Ionic arcade with a pedestal is shown in *fig.* 905. The whole area is 448 between the axes of the columns; that of the void, 228. The entablature's area is 73, and the supporting parts 146. The ratio, therefore, of the load to the support is $\frac{73}{146} = \cdot 5$, and supports and weights are very nearly equal to the void. The height of the pedestal is 6 modules, the opening 11 modules, and the width of a pier 4 modules and 12 parts.

Once more returning to the detail on which the above proportions are based, and which in this as in the following example we think it better to supply, observing, as before, that the numbers above stated are given roundly, we shall have in the Ionic arcade,

Whole area, 28·66 × 15·66 - - - - - -		= 448·81
Area of semi-arch, $\frac{11 \times 11 \times \cdot 7854}{2}$	= 47·01	
Below it, 16·5 × 11 -	= 181·50	
Total area of voids, therefore,		= 228·51
		220·30
Entablature, 15·66 × 4·7 - - - - - -		= 73·50
Leaves for supporting parts - - - - - -		146·80

Whence it will be seen that the round numbers first given are shown to be sufficiently accurate for exemplification of the law, and that the further we examine the hypothesis the more closely we find it connected with the theory of weights and loads that has occupied a very considerable portion of this Book, and which we hope may not have had the effect of exhausting the reader's patience. We trust we shall have his pardon for pursuing the course we have taken.

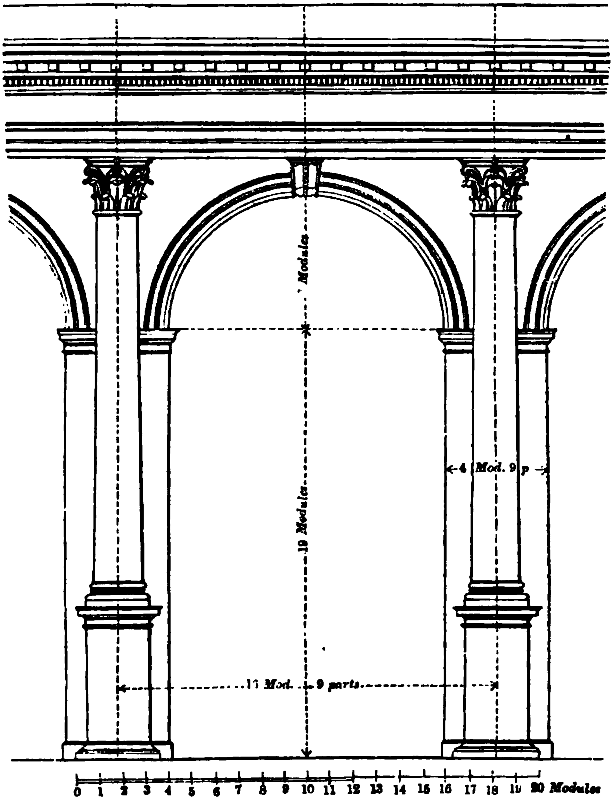
Modules
19 Modules
4 Mod. 9 p
16 Mod. 9 parts
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 Modules

Fig. 906.

2631. *Fig.* 906. is an arcade with pedestals of the Corinthian order. Its total area is 528, that of the void 284, the area of the entablature 84, and that of the supporting parts 159. Hence, the ratio of the load to the support is $\frac{84}{159}$ = ·52, and the supports and weight are equal in area to the void within a very small fraction. The height of the pedestal is 6¼ modules, the opening is 12 modules wide, and the width of a pier is 4 modules and 9 parts.

We here close the curious proofs of a law whose existence, we believe, has never been suspected by modern architects. It was clearly unknown to Rondelet, and but for the work of Lebrun already quoted, we might never have been led to the investigation of it. That author himself, as we believe, did not entertain any notion of it.

In the Corinthian arcade with pedestal we have

Whole area, 32 x 16·5 - - - - - - -		=528·00
Area of semi-arch, $\frac{12\times12\times\cdot7854}{2}$	= 56·05	
Below it, 19 x 12 -	=228·00	
Total area of voids, therefore,		=284·05
		243·95
Entablature, 16·5 x 5·09 - - - - - -		= 84·10
Leaves for supporting parts - - - - - -		159·85

Thus, again, the law seems to be borne out, and to prove that the assumptions we have been making are not those of empiricism.

2632. In *fig.* 907. are collected the imposts and archivolts used in the arcades of the different orders.

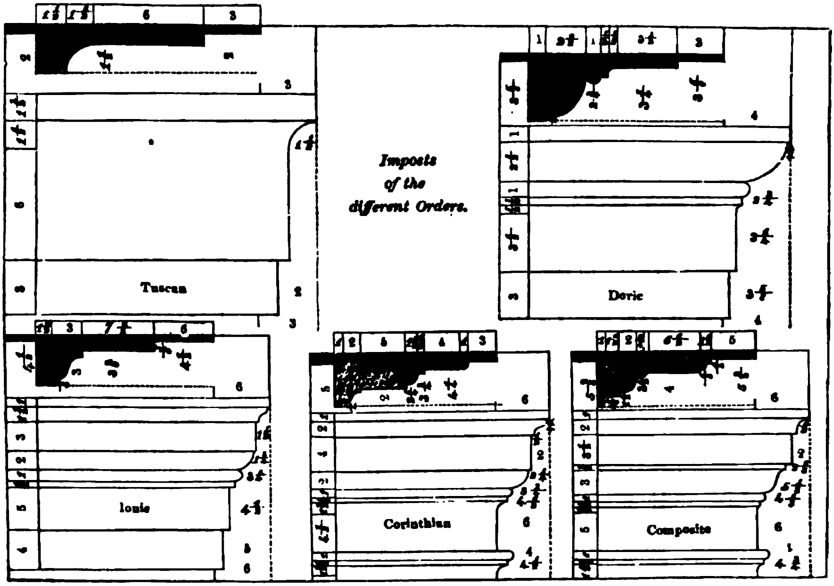

Fig. 907.

2633. We are not of the opinion of Sir William Chambers in respect of the arcades which Vignola has given; that author had not, we think, critically examined their composition, and we confess we do not think his own examples are improvements on those of the master in question; but we are willing to admit that in the examples of arcades with pedestals, they would have been much improved by assigning a greater height generally to the plinths of the pedestals, which are, doubtless, much too low, and might be well augmented by adding to them a portion of the dies of the pedestals.

2634. Great as is our admiration of Palladio, we do not think it necessary to say more relative to his arcades, than that he has given only designs of arches with pedestals, and that their height is from one and two thirds to two and a half of their width. His piers are generally 3⅔ modules, except in the Composite order, wherein they are 4⅓ modules.

2635. Scamozzi makes his Tuscan arch a little less than double its width, increasing the height gradually to the Corinthian arch with pedestals to nearly twice and a half the width. He diminishes his piers as the delicacy of the order increases, his Corinthian piers being only 3⅔ modules in width. We do not, however, think it necessary to dwell longer on this part of the subject, and shall close it by observing that the impost of the arch should not much vary from half a module in height, and that the width of the archivolt, which should touch the shaft of the column or pilaster in the geometrical elevation, at its springing, is necessarily prescribed by the width of pier left after setting out the column upon it. Where columns are used on piers, their projection must be such that the most prominent member of the impost should be in a line with the axis of the column on the transverse section. In Ionic, Composite, and Corinthian arcades, however, it may project a little beyond the axis of the columns, to avoid the disagreeable mutilations which are otherwise rendered necessary in the capitals. Arcades should project not less than their width from the front of the wall which backs them." With regard to their interior decoration," says Chambers, " the portico may either have a flat ceiling or be arched in various manners. Where the ceiling is flat, there may be on the backs of the piers, pilasters of the same kind and dimensions with the columns on their fronts; facing which pilasters there must be others like them on the back wall of the portico. Their projection as well as that of those against the back of the piers may be from one sixth to one quarter of their diameter. These pilasters may support a continued entablature, or one interrupted and running across the portico over every two pilasters to form coffers; or the architrave and frieze only may be continued, while the cornice alone is carried across the portico over the pilasters as before, and serves to form compartments in the ceiling, as is done in the vestibule of the Massini palace at Rome, and in the great stable of the King's mews, near Charing Cross," — no longer in existence, having been destroyed to make way on its site for the execrable mass of absurdity to which the government who sanctioned it have facetiously given the name of National Gallery. Chambers thus continues: — "Where the portico is arched, either with a semi-circular or elliptical vault, the backs of the piers and the inner wall of the portico may be decorated with pilasters, as is above described, supporting a regular continued entablature, from a little above which the arch should take its spring, that no part of it may be hid by the projection of the cornice. The vault may be enriched with compartments of various regular figures, such as hexagons, octagons, squares, and the like, of which, and their decorations, several examples are given among the designs for ceilings." Of these we shall hereafter give figures in the proper place. "But when the vault is groined, or composed of flats, circular or domical coves, sustained on pendentives, the pilasters may be as broad as are the columns in front of the piers, but they must rise no higher than the top of the impost, the mouldings of which must finish and serve them instead of a capital, from whence the groins and pendentives are to spring, as also the bands or *arcs-doubleaux* which divide the vault."

2636. In the examples of arcades, we have followed those given by Chambers, as exhibiting a variety which may be instructive to the student, and at the same time afford hints for other combinations. *Fig.* 908. is one of the compositions of Serlio, and is an expedient for arching in cases where columns have been provided, as in places where the use of old ones may be imposed on the architect. The larger aperture may be from 4½ to 5 diameters of the column in width, and in height double that dimension. The smaller opening is not to exceed two thirds of the larger one, its height being determined by that of the columns. Chambers thinks, and we agree with him, that this sort of disposition might be considerably improved by adding an architrave cornice or an entablature to the column, by omitting the rustics and by surrounding the arches with archivolts. It is not to be inferred, because this example is given, that it is inserted as one to be followed except under very peculiar circumstances. Where an arrangement of this kind is adopted, care must be used to secure the angles by artificial means.

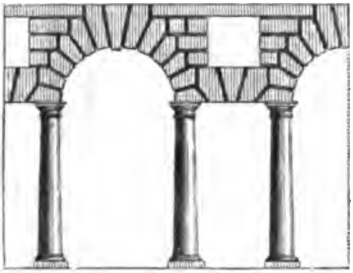
Fig. 908.

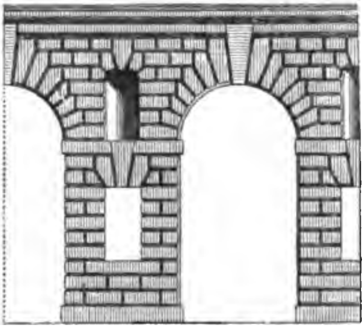
Fig. 909.

2637. *Fig.* 909. is given from the cortile of the castle at Caprarola by Vignola, a structure which in the First Book of this work we have (346.) already mentioned. The height of the arches is somewhat more than twice their width. From the under side of the arch to the top of the cornice is one third of the height of the arch, the breadth of whose pier is equal to that of the arch, and the aperture in the pier about one third of its breadth.

2638. A composition of Bramante, executed in the garden of the Belvedere at Rome, is given at *fig.* 910. The arch in height is somewhat more than twice its width, and the

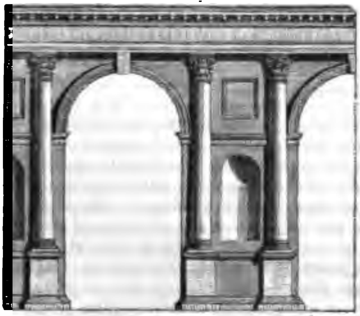
Fig. 910.

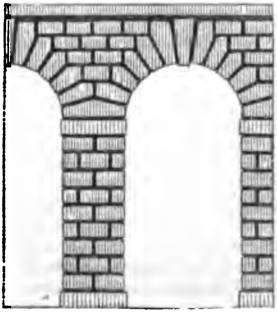
Fig. 911.

breadth of the pier equal to the opening. By dividing the latter into twelve parts we have a measure which seems to have prevailed in the mind of the architect, inasmuch as two of them will measure the parts of the pier supporting the archivolts, four the space for the two columns, two for the intervals between the niche and the columns, and four for the niche. Half the diameter of the arch measures the height of the pedestal; the columns are of the height of ten diameters, and their entablature one quarter of the height of the columns. The impost and archivolt are each equal to half a diameter of the column.

2639. *Fig.* 911. is an example whose employment is not uncommon in the designs of Palladio, and was considered by our great countryman Inigo Jones to be worthy of his imitation. The arch may be taken at about twice its width, and the pier not less than one nor more than two thirds of the width of the aperture.

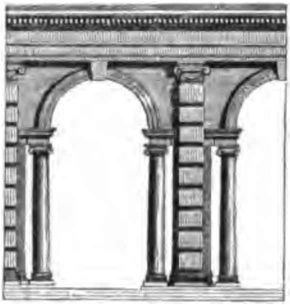
Fig. 912.

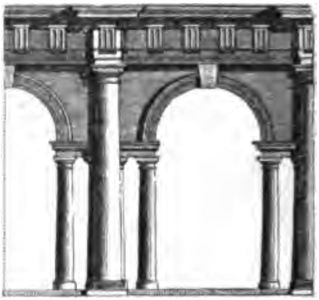
Fig. 913.

2640. The example in *fig.* 912. is from the hand of Vignola, and was executed for one of the Borghese family at Mondragone, near Frascati. In it the arch is a little more in height than twice its width, and the breadth of the pier columns supporting the arch include a little less than the width of the arch itself. We are not quite satisfied in having here produced it as an example, though, compared with the following one, we scarcely know whether we should not on some accounts prefer it.

2641. The last example (*fig.* 913.) is one by that great master, Palladio, from the basilica at Vicenza. From the figure it is impossible to judge of its beauty in execution, neither can any imitation of it, unless under circumstances in every respect similar, produce the sensation with which the building itself acts on the spectator; yet in the figure it appears meagre and nothing worth. We can therefore easily account for the conduct of the critics, as they are called, who, never having seen this master's works, indulge in ignorant speculations of the pictorial effects which his compositions produce. Though not entirely agreeing with Chambers in his concluding observations on arcades and arches, we may safely transfer them to these pages. "The most beautiful proportion," he observes, "for compositions of this kind is, that the aperture of the arch be in height twice its width; that the breadth of the pier do not exceed that of the arch, nor be much less; that the small order be in height two thirds of the large columns, which height being divided into nine parts, eight of them must be for the height of the column, and the ninth for the height of the architrave cornice, two fifths of which should be for the architrave and three for the cornice. The breadth of the archivolt should be equal to the superior diameter of the small columns, and the keystone at its bottom must never exceed the same breadth."

Sect. XI.

ORDERS ABOVE ORDERS.

2642. Vitruvius, in the fifth chapter of his book "On the Forum and Basilica," in both which species of buildings it is well known that orders above orders were employed, thus instructs his readers: — "The upper columns are to be made one fourth less than those below" (*quarta parte minores quam inferiores sunt constituendæ*), "and that because the latter, being loaded with a weight, ought to be the stronger; because, also, we should follow the practice of nature, which in straight-growing trees, like the fir, cypress, and pine, makes the thickness at the root greater than it is at top, and preserves a gradual diminution throughout their height. Thus, following the example of nature, it is rightly ordered that bodies which are uppermost should be less than those below, both in respect of height and thickness." It is curious that the law thus given produces an exactly similar result to that laid down by Scamozzi, p. 2. lib. v. cap. ii., whereon we shall have more presently to speak. Galliani, Chambers, and others have considered the above-quoted passage of Vitruvius in connection with another in chap. vii. of the same book, which treats of the portico and other parts of the theatre, wherein the author states, after giving several to this question unimportant details, "The columns on this pedestal" (that of the upper order) "are one fourth less *in height*" (quartâ parte minores *altitudine* sint) "than the lower columns." The reader will here observe the word *altitudine* is introduced, which does not appear in the passage first quoted; and we beg him, moreover, to recollect that the last quotation relates entirely to the scene of the ancient theatre, in which liberties were then taken with strict architectural proportion as much as they are in these later days. Those who think that because Vitruvius interlarded his work with a few fables, he is therefore an author not worth consulting, as ephemeral critics have done in respect of that great master of the art, Palladio, may opine we have wasted time in this discussion; but, adopting the old maxim of Horace, "Non ego paucis offendar maculis," we shall leave them to the exposure which, with the instructed architect, their own ignorance will ultimately inflict on them, and to the enjoyment of the felicity attendant on a slight knowledge of the subject a person is in the habit of handling.

2643. We will now place before the student our own reading and explanation of the passage of Vitruvius relative to the use of orders above orders, and attempt to show what we conceive to be its real meaning. In *fig.* 914. the diagram exhibits an Ionic placed above a Doric column: the entablature (which however does not belong to the consideration) being in both cases one fourth of the height of the column. Inasmuch as in our previous rules (following Vignola) it will be recollected that the module of the Doric order is subdivided into twelve, whilst that of the Ionic is subdivided into eighteen parts, we must, for the purpose of obtaining an uniformity of measures in both orders, reduce those of either to the other to obtain similar dimensions. Instead, therefore, of measuring the upper order by itself, which would not afford the comparison sought, we shall have to reduce its established measures to those of the lower one, or Doric, and this, as well as the measurement of the lower order itself, is taken in modules and decimal parts of its semidiameter. Thus, the lower order being 2 modules at its bottom diameter and 1·666 modules at its upper diameter, the means, without descending to extreme mathematical nicety, may be taken at 1·833, which multiplied by the height, 18 modules = 32·994, the area of a section through the centre of the column. Now if the upper columns are to be the same thickness at the bottom as the lower ones are at the top, that is, 1·666 module of the lower order, their upper diameters will be 1·387 (that is, five sixths of the lower diameter), and the mean will be 1·526, which, multiplied by 16, the height, = 24·416 the area of a section down the centre of the column, and just one fourth less than that of the lower column. The investigation tends to show us that we should not lightly treat the laws laid down by Vitruvius and his followers at the revival of the arts, for we may be assured that in most cases they are not empirical, but founded on proper principles. We cannot, however, leave this point without giving another reason, which is conclusive against Chambers's construction of the passage; it is, that supposing the upper column's lower diameter to be the same or nearly so as the lower column's upper diameter, if the *fourth* part had relation to the height instead of the bulk, we should have had the absurdity in the illustration above given, of an Ionic column in the second order only six and three quarters diameters high, whilst the lower or Doric is nine diameters in height.

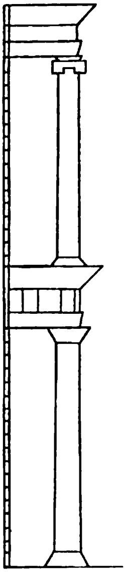
Fig. 914.

2644. Scamozzi, we doubt not, thought as we have expressed ourselves on this subject, and we here translate the words he uses in the eleventh chapter of his sixth book (second part). "Hence it is more satisfactory, and they succeed better and are more pleasing to the eye, when these columns (the upper ones) are made according to their proper diminution, so that the lower part of the upper column may be just the thickness of the upper part of the lower one, and so from one to the other, as may be seen in the Ionic order of the Theatre of Marcellus and other edifices; and this is the reason and natural cause that it is the same as though out of a long and single tree the shafts were cut out one after the other."

2645. The laws of solidity seem to require that where more than one order is used, the strongest is to occupy the lower situation; thus the Doric is placed on the Tuscan, the Ionic on the Doric, the Corinthian on the Ionic, and the Composite on the Corinthian; though, with respect to the last, we find examples of importance wherein the reverse has been the case. Two tiers of columns should not be of the same order, neither should an intermediate order be omitted; such, for instance, as placing the Ionic on the Tuscan column, or the Corinthian on the Doric; for by this practice many irregularities are introduced, especially in the details of the members.

2646. Frontwise the axes of the upper and lower columns must be in the same vertical plane, but viewed in flank this is not absolutely necessary; they should not, however, deviate too much from it. In the theatre of Marcellus the axes of the upper columns are nearly a foot within those of the Doric below them; but circumstances required this, and there is no great objection to the practice if the solidity of the structure be not lessened by it. Chambers observes that the retraction should never be greater than at the theatre of Marcellus, where the front of the plinth in the second order is in a line with the top of the shaft in the first. When the columns are detached, they should be placed centrally over each other, so that the axes of the upper and under ones may form one continued line, by which means solidity is gained as well as a satisfactory result to the eye. As to the false bearings of the bases of the upper order on the profile, this is a matter neither really affecting stability nor the appearance of the design.

2647. In England there are not many examples of orders above orders, while on the Continent the practice has not been uncommon; but it is always a matter of great difficulty so to arrange them as to avoid irregularities where triglyphs and modillions in the same design meet in the composition. We have used the figures of Chambers for our illustration here, because they are nearly coincident with the rules of Vitruvius and Scamozzi, and we shall now place them before the reader, observing that the irregularities alluded to are almost altogether avoided.

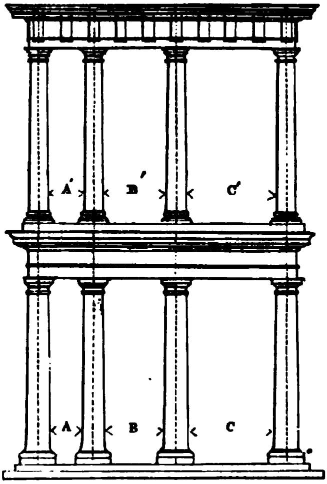

Fig. 915.

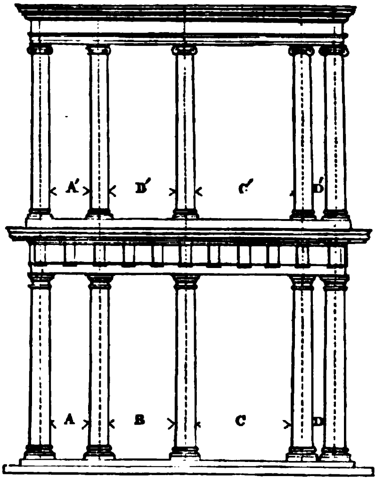

Fig. 916.

2648. *Fig.* 915. exhibits the Doric over the Tuscan order. The intervals A, B, and C are respectively 2⅛, 4¼, and 6⅓ modules; and A', B', and C', 3, 5½, and 8 modules of their order. The entablature of the lower order is 3½ modules, the column, including base and capital, being 14 modules high; and the entablature of the upper order is 4 modules high, the column with its base and capital being 16 modules in height.

2649. The distribution of the Doric and Ionic orders is given in *fig.* 916., wherein the intervals A, B, and C are respectively 3, 5½, and 8 modules; D, ·7 module; and A', B', C', and D' respectively 4, 7, 10, and 1¼ modules. The Doric order in this example is 20 modules high, whereof 4 are assigned to the entablature; the Ionic 22 modules high, whereof 4 belong to the entablature.

2650. In *fig.* 917. is represented the Corinthian above the Ionic order; the intervals A, B, C, D are respectively 5, 6, 7, and 1 modules, and those of A', B', C', D' respectively 6·4, 7·6, 8·8, 1·6 modules; the lower order is 22½ modules high, 18 being given to the column with its base and capital; and the upper or Corinthian order is 24½ modules high, whereof 20 belong to the height of the column, including its base and capital.

2651. The last (*fig.* 918.) is of the Corinthian order above and Composite below. In the lower order the intervals A, B, C, D are 4⅔, 6, 7, and 1 modules respectively, and A', B', C', and D', in the upper order, 6, 7·6, 8·8, and 1·6 modules respectively. The whole height of the Corinthian order is 25 modules, whereof 5 are given to the entablature; the Composite order here is 24½ modules, of which 20 belong to the column, including the base and capital.

2652. We insert the observations of Chambers relative to the above four figures, which,

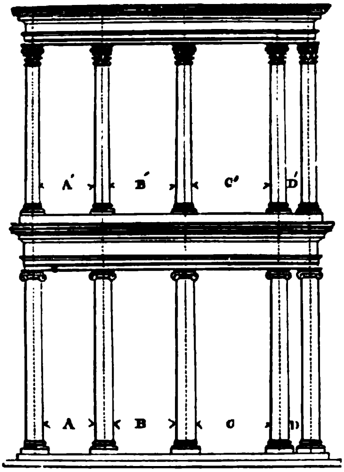

Fig. 917.

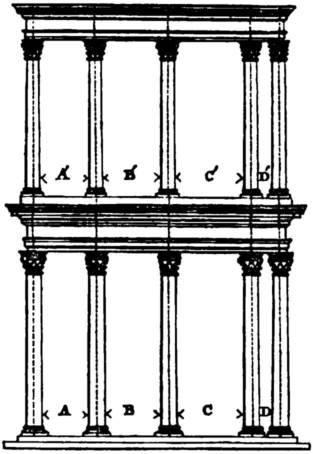

Fig. 918.

as we have adopted them, shall be in his own words. "Among the intercolumniations there are some in the second orders extremely wide, such as the Ionic interval over the Doric aræostyle; the Composite and Corinthian intervals over the Ionic and Composite aræostyle, which, having a weak meagre appearance, and not being sufficiently solid, excepting in small buildings, are seldom to be suffered, and should seldom be introduced. The most eligible are the eustyle and diastyle for the first order, which produce nearly the diastyle and aræostyle in the second." Speaking of the use of pedestals in orders above orders, the author thus proceeds: — "Many architects, among which number are Palladio and Scamozzi, place the second order of columns on a pedestal. In compositions consisting of two stories of arcades this cannot be avoided, but in colonnades it may and ought; for the addition of the pedestal renders the upper ordonnance too predominant, and the projection of the pedestal's base is both disagreeable to the eye and much too heavy a load on the inferior entablature. Palladio, in the Barbarano palace at Vicenza, has placed the columns of the second story on a plinth only, and this disposition is best; the height of the plinth being regulated by the point of view, and made sufficient to expose to sight the whole base of the column. In this case the balustrade must be without either pedestals or half balusters to support its extremities, because these would contract and alter the form of the column; its rail or cap must be fixed to the shafts of the columns, and its base made level with their bases; the upper torus and fillet of the columns being continued in the interval, and serving as mouldings to the base of the balustrade. The rail and balusters must not be clumsy; wherefore it is best to use double-bellied balusters, as Palladio has done in most of his buildings, and to give the rail a very little projection, that so it may not advance too far upon the surface of the column, and seem to cut into it. In large buildings the centre of the baluster may be in a line with the axis of the column; but in small ones it must be within it, for the reason just mentioned. The height of the balustrade is regulated in a great measure by its use, and cannot well be lower than three feet, nor should it be higher than three and a half or four feet. Nevertheless, it must necessarily bear some proportion to the rest of the architecture, and have nearly the same relation to the lower order, or whatever it immediately stands upon, as when a balustrade is placed thereon chiefly for ornament. Wherefore, if the parts are large, the height of the balustrade must be augmented, and if they are small it must be diminished; as is done in the Casino at Wilton, where it is only two feet four inches high, which was the largest dimension that could be given to it in so small a building. But that it might, notwithstanding its lowness, answer the intended purpose, the pavement of the portico is six inches lower than the bases of the columns, and on a level with the bottom of the plat-band that finishes the basement."

We must here leave this subject, recommending the student to an intimate acquaintance with the various examples that have been executed, and further advising him to test each of the examples that may fall under his notice by the principles first adverted to in this section, as the only true means of arriving at a satisfactory result.

Sect. XII.

ARCADES ABOVE ARCADES.

2653. As the disposition of one arcade upon another is, under certain regulations, subject to the same laws of voids and solids as the simple arcade of one story, which has formed the subject of a previous section, we shall no further enter into the rules of its combination than to offer a few general observations on the matter in question; and herein, even with the reproach of a want of originality, we shall draw largely on our much-quoted author, Chambers, whose language and figures we are about to use. So sound, indeed, is the doctrine of Chambers in this respect, and so well founded on what has been done by those whom we consider the greatest masters, that we should not be satisfied without transferring his dicta to these pages, and that without any alteration.

2654. "The best," says Chambers, "and, indeed, the only good disposition for two stories of arcades, is to raise the inferior order on a plinth, and the superior one on a pedestal, as Sangallo has done at the Pallazzo Farnese; making both the ordonnances of an equal height, as Palladio has done at the Basilica of Vicenza."

2655. "Scamozzi, in the thirteenth chapter of his sixth book, says that the arches in the second story should not only be lower, but should also be narrower, than those in the first; supporting his doctrine by several specious arguments, and by the practice, as he says, of the ancient architects in various buildings mentioned by him. In most of these, however, the superior arches are so far from being narrower, that they are either equal to or wider than the inferior ones. In fact, his doctrine in this particular is very erroneous, entirely contrary to reason, and productive of several bad consequences; for if the upper arches be narrower than the lower ones, the piers must of course be broader, which is opposite to all rules of solidity whatever, and exceedingly unsightly. The extraordinary breadth of the pier on each side of the columns in the superior order is likewise a great deformity; even when the arches are of equal widths it is much too considerable. Palladio has, in the *Carità* at Venice, and at the Palazzo Thiene in Vicenza, made his upper arches wider than the lower ones, and I have not hesitated to follow his example; as by that means the weight of the solid in the superior order is somewhat diminished, the fronts of the upper piers bear a good proportion to their respective columns, and likewise to the rest of the composition."

2656. "In a second story of arcades there is no avoiding pedestals. Palladio has, indeed, omitted them at the Carità, but his arches there are very ill proportioned. The extraordinary bulk and projection of these pedestals are, as before observed, a considerable defect; to remedy which in some measure they have been frequently employed without bases, as in the theatre of Marcellus, on the outside of the Palazzo Thiene, and that of the Chiericato in Vicenza. This, however, helps the matter but little; and it will be best to make them always with bases of a moderate projection, observing at the same time to reduce the projection of the bases of the columns to ten minutes only, that the die may be no larger than is absolutely necessary; and in this case particular care must be taken not to break the entablature over each column of the inferior order, because the false bearing of the pedestal in the second order will by so doing be rendered far more striking, and in reality more defective, having then no other support than the projecting mouldings of the inferior cornice. There is no occasion to raise the pedestals of the second order on a plinth, for as they come very forward on the cornice of the first order, and as the point of view must necessarily be distant, a very small part only of their bases will be hid from the eye."

2657. "The balustrade must be level with the pedestals supporting the columns; its rail or cornice and base must be of equal dimensions, and of the same profile with theirs. It should be contained in the arch and set as far back as possible, that the form of the arch may appear distinct and uninterrupted from top to bottom; for which reason, likewise, the cornice of the pedestals must not return nor profile round the piers, which are to be contained in straight perpendicular lines from the imposts to the bases of the pedestals. The back of the rail may either be made plain or sunk into a panel in form of an open surbase, for so it will be most convenient to lean upon, and it should be in a line with or somewhat recessed within the backs of the piers. The back part of the balustrade may be adorned with the same mouldings as the bases of the piers, provided they have not much projection; but if that should be considerable, it will be best to use only a plinth crowned with the two upper mouldings, that so the approach may remain the more free."

2658. In *fig.* 919. is a Doric above a Tuscan arcade, from the example given by Chambers, whereon, before giving the dimensions of the different parts, we shall merely observe of it that the voids or arcades themselves are in round numbers to the solids as 295 to 205, being vastly greater. We are inclined to think that the voids in this case are rather too great in volume, and that had they been reduced to one half exactly, the proportions would have been somewhat more pleasing. It is true that a trifling irregularity would have been introduced into the triglyphs of the upper order, or rather the metopæ between them; but that might have been easily provided against by a very trifling alteration in the height of the frieze itself. This fault of making the voids too large pervades Chambers's examples, and but that we might have been thought too presuming we should have slightly altered the proportions, little being requisite to bring them under the laws which we have thought to be founded on reason and analogy. We have indeed throughout this work refrained from giving other than approved examples, preferring to confine ourselves to observations on them when we have not considered them faultless.

2659. In the figure the clear width of the lower arcade is 7⅜, and its height 14¼ modules. The width of each pier is 1 module. Of the upper arcade the width is 9⅓, and the height 18·233 modules. The width of the piers is 1¼ module each. The height of the plinth of the lower order is 1½ module, that of the column, including base and capital, 14⅓ modules, the entablature 3⅓. The height of the pedestal of the upper order is 3·733 modules, of the column with its base and capital 16, and of the entablature 3·733 modules. In the proportions between the voids and solids above taken the balustrade is not considered as a solid, because, in fact, it is nothing more than a railing for the protection of those using the upper story. As we have expressed our desire to give the examples of others rather than our own, we feel bound to recommend the student to set up the diagram in question, with the simple alteration of reducing the solids nearly to an equality with the voids, which may be done with sufficient accuracy by assigning to the lower arcade a module less in width than Chambers has done; and we venture to say that he will be surprised at the difference, as regards grace and elegance, which will result from the experiment. It is to be understood that no change is proposed in the other dimensions of the ordonnance, the width of piers, orders, entablatures, all remaining untouched.

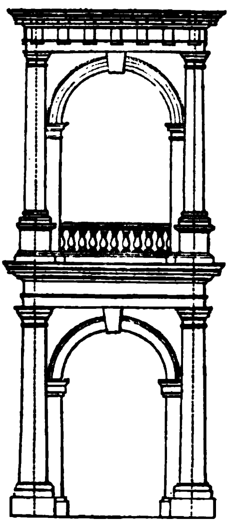
Fig. 919.

2660. In *fig.* 920. we give another example from Chambers, which, in our opinion, requires a rectification to bring it into proper form. Herein the Ionic is used above the Doric arcade, and the voids to the solids are as 3·33 to 2·98, being much more than equal to them. In this, as in the former example, we should have preferred a greater equality between the solids and voids, though in that under consideration there is a nearer approximation to it.

2661. In the figure the clear width of the lower arch is 8¼, and its height 16⅛ modules; the width of each pier is 1 module. Of the upper arcade the width is 10¼, and the height 20½ modules. The width of the piers is 1¼ module each. The height of the plinth of the lower order is 1½ module that of the column, including the base and capital, 16⅛ modules, and of the entablature 4 modules. The height of the pedestal of the upper order 4 modules, of the column, including base and capital, 18 modules, and of the entablature 4, and of the balustrade above it 3⅛.

2662. The dimensions of the Ionic and Corinthian arcades in *fig.* 921. are as follow: — Clear width of lower arch 9 modules, its height 18⅛ modules. The width of each pier is 1 module. Of the upper arcade the width of an arch 15⅜ modules, and its height 23 modules. The width of

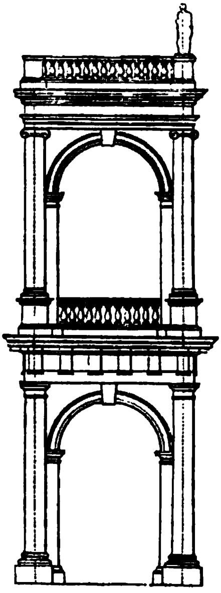
Fig. 920.

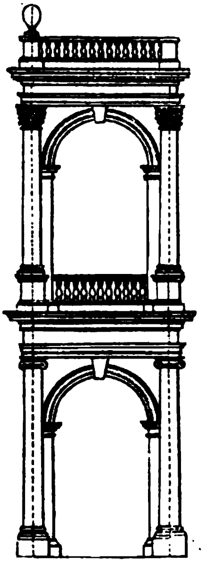
Fig. 921.

the piers is 1¼ module each. The height of the plinth to the lower order is 1⅜ module; of the column, including base and capital, 18 modules; the entablature 4¼ modules. The pedestal of the upper order is 4½ modules high; column, including base and capital, 20 modules; entablature 4¼ modules; and, lastly, the balustrade is 3⅜ modules in height.

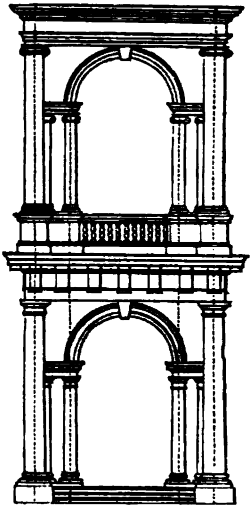

Fig. 922.

2663. *Fig.* 922. is an arrangement adopted by Palladio in his basilica at Vicenza, being the dimensions, or nearly, of the arcades on the flanks. The intermediate ones are much wider. In the basilica, however, the entablature breaks round the columns of the orders. The width between the axes of the columns of the lower order is 15 of their modules. The arch is 15 modules high and 7⅝ wide. The order wherefrom the arch springs is 10⅝ modules high; from axis to axis of the small columns in the lower arcade is 9 modules. The height of the plinth is 1¼ module, of the principal columns, including bases and plinths, 16¼ modules, and of their entablature 4 modules. In the upper arcade the distance between the axes of the principal columns is 18 of their modules. Their pedestals are 4 modules high, the columns, including bases and capitals, 18 modules, and entablature 4 modules high. The width of the arch is 9⅜ modules, and its height 20⅝ modules. The height of the small columns is 11·733 modules high, including their entablature.

2664. The use of arcades above arcades seems from its nature almost confined to public buildings, as among the ancients to their theatres and amphitheatres. In the interior quadrangles or courts of palaces they have been much employed on the Continent, and in the magnificent design made by Inigo Jones for the palace at Whitehall are to be found some very fine examples.

Sect. XIII.

BASEMENTS AND ATTICS.

2665. When the order used for decorating the façade of a building is placed in the middle or second story, it is seated on a story called the *basement*. The proportion of its height to the rest must in a great measure depend on the use to which its apartments are to be appropriated. "In Italy," observes Chambers, "where their summer habitations are very frequently on that floor, the basements are sometimes very high. At the palace of Porti, in Vicenza, the height is equal to that of the order placed thereupon; and at the Thiene, in the same city, its height exceeds two thirds of that of the order, although it be almost of a sufficient elevation to contain two stories; but at the Villa Capra, and at the Loco Arsieri, both near Vicenza, the basement is only half the height of the order; because in both these the ground floor consists of nothing but offices." It may hence be gathered that no absolute law can be laid down in reference to the height of a basement story. Yet we may state, generally, that a basement should not be higher than the order it is to support, for it would in that case detract from the principal part of the composition, and, in fact, would be likely to interfere with it. Besides which, the principal staircase then requires so many steps that space is wasted for their reception. "Neither," says Chambers, "should a basement be lower than half the height of the order, if it is to contain apartments, and consequently have windows and entrances into it; for whenever that is the case the rooms will be low, the windows and doors very ill formed, or not proportional to the rest of the composition, as is observable at Holkham: but if the only use of the basement be to raise the ground floor, it need not exceed three, four, or at the most five or six feet in height, and be in the form of a continued pedestal."

2666. Basement stories are decorated generally with rustic work of such various kinds, that we fear it would be here impossible to describe or represent their varieties. Many are capriciously rock-worked on their surface, others are plain, that is, with a smooth surface. The height of each course, including the joints, should on no account be less than one module of the order which the basement supports; their length may be from once and a half to thrice their height. As respects the joints, these may be square or chamfered off. When square joints are used, they should not be wider than one eighth part of the height of the rustic itself, nor narrower than one-tenth, their depth not exceeding their width. When the joints are chamfered, the chamfer should be at an angle of forty-five degrees, and the whole width of the joint from one third to one fourth of the height of the rustic.

2667. The courses are sometimes (often on the Continent) laid without showing vertical joints; but, as Chambers says, this "has in general a bad appearance, and strikes as if the building were composed of boards rather than of stone. Palladio's method seems far preferable, who, in imitation of the ancients, always marked both the vertical and the horizontal joints; and whenever the former of these are regularly and artfully disposed, the rustic work has a very beautiful appearance." We shall presently make a few remarks on the subject of rustics; but here, to continue and finish that more immediately under consideration, have to add, that when a high basement is used, it is not uncommon to crown it with a cornice, as may be seen in *fig.* 909.; but the more common practice is to use a platband only (as in *fig.* 911.), whose height should not be greater than that of a rustic exclusive of the joint. Of a similar height should be made the zoccolo or plinth; but this may, and ought, perhaps, to be somewhat higher. When arches occur in basements, the platband, which serves for the impost, should be as high as a course of rustics, exclusive of the joint; and if the basement be finished with a cornice, such basement should have a regularly moulded base at its foot; the former to be about one thirteenth of the whole height of the basement, and the base about one eighteenth, without the plinth.

2668. The Attic — which is used instead of a second order where limits are prescribed to the height of a building, examples whereof may be seen at Greenwich Hospital, and in the Valmarano palace, by the great Palladio, at Vicenza — should not exceed in height one-third of the order whereon they are placed, neither ought they to be less than one quarter. Bearing some resemblance to a pedestal, the base, die, and cornice whereof they are composed may be proportioned much in the same way as the respective divisions of their prototypes. They are sometimes continued without, and sometimes with, breaks over the column or pilaster of the order which they crown. If they are formed with pilasters, such ought to be of the same width as the upper diameter of the order under them, never more. In projection they should be one quarter of their width at most. They may be decorated with sunk moulded panels if necessary; but this is a practice rather to be avoided, as is most especially that of using capitals to them — a practice much in vogue in France under Louis XV.

2669. We now return to the subject of the rock-worked rustic, whereof, above, some notice was promised. The practice, though occasionally used by the Romans, seems to have had its chief origin in Florence, where, as we have in a former Book (329.) observed, each palace resembled rather a fortification than a private dwelling. Here it was used to excess; and if variety in the practice is the desire of the student, the buildings of that city will furnish him with an almost infinite number of examples. The introduction of it gives a boldness and an expression of solidity to the rustics of a basement which no other means afford. In the other parts of Italy it was sparingly applied, but with more taste. Vignola and Palladio seem to have treated it as an accident productive of great variety rather than as a means of decoration. The last-named architect has in the Palazzo Thiene carried it to the utmost extent whereof it is susceptible. Yet, with this extreme extent of application, the design falls from his hands full of grace and feeling. To imitate it would be a dangerous experiment. De Brosse failed at the Luxembourg, and produced an example of clumsiness which in the Palazzo Pitti does not strike the spectator.

2670. Rustics and rockwork on columns are rarely justifiable except for the purpose of some particular picturesque effect which demands their prominence in the scene, or street view, as in the gateway at Burlington House in Piccadilly, — a splendid monument of the great talent of Lord Burlington.

Sect. XIV.

PILASTERS.

2671. Pilasters, or square columns, were by the Romans termed *antæ*, by the Greeks *parastatæ*. This last word implies the placing one object standing against another, a sufficiently good definition of the word, inasmuch as in ninety-nine cases out of a hundred they are engaged in or backed against a wall, or, in other words, are portions of square columns projecting from a wall.

2672. It is usual to call a square column, when altogether disengaged from the wall, a *pillar* or *pier*; and we are inclined to think, notwithstanding the alleged type of trees, that the primitive supports of stone buildings were quite as likely to have been square as round, and that the inconvenience attendant upon square angles may have led the earliest builders to round off the corners, and gradually to bring them to a circular plan. Isolated pillars are rarely found among the examples left us by the ancients; the little temple at Trevi furnishes, indeed, an example, but not of the best period of the art. The principal points to be attended to in their use are their projection, diminution, the mode of uniting the entablature over them with that of their columns, and their flutings and capitals.

2673. In respect of the projection of pilasters, Perrault says they should project one half, and not exceed that by more than a sixth, as in the frontispiece of Nero, unless circumstances require a different projection. The pilasters of the Pantheon project only a tenth part of their width; and sometimes, as in the forum of Nerva, they are only a fourteenth part. But when pilasters are to receive the imposts of arches against their sides, they are made to project a fourth part of their diameter; and this is a convenient proportion, because in the Corinthian order the capital is not so much disfigured. Hence, when pilasters are made to form re-entering angles, they should project more than half their diameter. Many and various opinions have been formed on the propriety of diminishing pilasters. Perrault, with whom we incline to agree, thinks that when one face only projects, pilasters should not be diminished. Those at the flanks of the portico of the Pantheon are without diminution. But when pilasters are on the same line as columns, we want to lay the entablature from one to the other without any projection, in which case the pilaster must be diminished in the same degree as the column itself, speaking of the front face, leaving the sides undiminished, as in the temple of Antoninus and Faustina. When the pilaster has two of its faces projecting from the wall, being on the angle, and one of those faces answers to a column, such face is diminished similarly to the column, as in the portico of Septimius, where the face not corresponding to the column receives no diminution. There are, however, ancient examples where no diminution is practised, as in the interior of the Pantheon, where it is so small as not to be very apparent, being much less than that of the column, as is also the case in the temple of Mars Ultor, and in the arch of Constantine. In these cases, the custom of the ancients is sometimes to place the architrave plumb over the column, which brings it within the line of the pilaster. This may be seen in the temple of Mars Ultor, in the interior of the Pantheon, and in the portico of Septimius. Sometimes this excess is divided into two parts, one whereof goes to the excess of projection of the architrave above the column, and the other half to the deficiency of extent above the pilaster, as in the forum of Nerva. The whole matter is a problem of difficult solution, which Chambers has avoided, but which, with reference to the examples we have cited, will not be attended with difficulty to the student in his practice.

2674. We have above seen that pilasters, when used with columns, are subject to the form and conditions of the latter. As to their flutings we are left more at liberty. In the portico of the Pantheon we find the pilasters fluted and the columns plain. This, however, may have been caused by the difficulty of fluting the latter, which are of granite, whilst the pilasters are of marble. On the other hand, we sometimes find the columns fluted and the pilasters plain, as in the temple of Mars Ultor, and the portico of Septimius Severus. Generally, too, it may be observed that when pilasters project less than half their diameter, their return faces are not fluted. In respect of the number of the flutes, if the examples of the ancients were any guide, could have been no fixed rule; for in the portico of the Pantheon, the arch of Septimius Severus, and that of Constantine, seven flutes only are cut on the pilasters, whilst the flutes of the pilasters in the interior of the Pantheon are nine in number. This, however, is to be observed, that the flutes must always be of an odd number, except in re-entering pilasters, wherein four are placed instead of three and a half, and five instead of four and a half, when the whole pilaster would have nine. This is done to prevent the ill effect which would be produced in the capital by the bad falling of the leaves over the flutes.

2675. We shall hereafter give from Chambers some representations of pilaster capitals, which, except as regards their width, resemble those of the order they accompany. The practice of the ancients in this respect was very varied. Among the Greeks the form of the pilaster capital was altogether different from that of the column, seeming to have no relationship to it whatever; but on this point the student must consult the works on Grecian antiquities, an example whereof will be found in *fig.* 883.

2676. A pilaster may be supposed to represent a column and to take its place under many circumstances; and, notwithstanding all that was said on the subject by the Abbé Laugier, many years ago, against the employment of pilasters altogether, we are decidedly of opinion that they are often useful and important accessories in a building. It would be difficult to enumerate every situation wherein it is expedient to use pilasters rather than insulated or engaged columns. In internal apartments, where the space is restricted, a column appears heavy and occupies too much room. The materials, morever, which can be obtained, often restrict the architect to the use of pilasters, over which the projections of the entablature are not so great; indeed, as the author in the *Encyclopedie Methodique* observes, a pilaster may be considered as a column in bas-relief, and is thus, from the diminished quantity of labour and material in it, simpler and more economical in application. That in houses and palaces of the second class the decoration by pilasters is of great service may be amply shown by reference to the works of Bramante, San Gallo, Palladio, and the other great masters of Italy, no less than in this country to those of Jones, Wren, and Vanbrugh.

2677. In profiling the capitals of Tuscan and Doric pilasters there can of course arise no difficulty; they follow the profiles of those over the columns themselves. In the capitals, however, of the other orders, some difficulties occur: these are thus noticed by Chambers. "In the antique Ionic capital, the extraordinary projection of the ovolo makes it necessary either to bend it inwards considerably towards the extremities, that it may pass behind the volutes, or, instead of keeping the volutes flat in front, as they commonly are in the antique, to twist them outwards till they give room for the passage of the ovolo. Le Clerc" (*Traité d'Architecture*) "thinks the latter of these expedients the best, and that the artifice may not be too striking, the projection of the ovolo may be considerably diminished, as in the annexed design" (*fig.* 923.), "which, as the moulding can be seen in front only, will occasion no disagreeable effect."

2678. "The same difficulty subsists with regard to the passage of the ovolo behind the angular Ionic volutes. Le Clerc therefore advises to open or spread the volutes sufficiently to leave room for the ovolo to pass behind them, as in the design" (*fig.* 924.) "annexed; which may be easily done, if the projection of the ovolo is diminished. Inigo Jones has in the Banqueting House made the two sides of the volutes parallel to each other, according to Scamozzi's manner, and at the same time has continued the ovolo in a straight line under them, so that the volutes have an enormous projection; which, added to the other faults of these capitals, renders the whole composition unusually defective and exceedingly ugly."

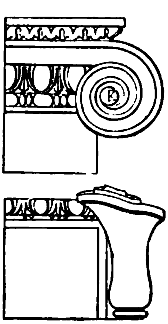
Fig. 923.

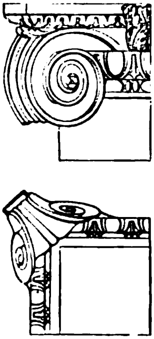
Fig. 924.

2679. "What has been said with regard to the passage of the ovolo behind the volutes in the Ionic order is likewise to be remembered in the Composite; and in the Corinthian the lip or edge of the vase or basket may be bent a little inwards towards its extremities, by which means it will easily pass behind the volutes. The leaves in the Corinthian and Composite capitals must not project beyond the top of the shaft, as they do at San Carlo in the Corso at Rome, and at the Banqueting House, Whitehall; but the diameter of the capital must be exactly the same as that of the top of the shaft. And to make out the thickness of the small bottom leaves, their edges may be bent a trifle outwards, and the large angular leaves may be directed inwards in their approach towards them, as in the annexed design" (*fig.* 925.), "and as they are executed in the church of the Roman college at Rome. When the small leaves have a considerable thickness, though the diameter of the capital is exactly the same as that of the shaft, in each front of the Composite or Corinthian pilaster capital, there must be two small leaves with one entire and two half large ones. They must be either of olive, acanthus, parsley, or laurel, massed, divided, and wrought, in the same manner as those of the columns are, the only difference being that they will be somewhat broader."

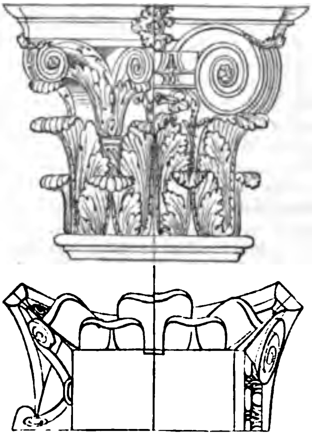
Fig. 925.

2680. It is desirable to avoid the use of pilasters at inward angles penetrating each other, because of the irregularity such practice produces in the entablatures and capitals. One break is quite as much as should be ever tolerated, though in many of the churches in Rome they are multiplied with great profusion of mutilated capitals and entablatures; "than which," observes Chambers, "nothing can be more confused or disagreeable."

2681. Neither should columns be allowed to penetrate each other, as they do in the court of the Louvre, inasmuch as the same irregularity is induced by it as we have above noticed in the case of pilasters.

Sect. XV.

CARYATIDES AND PERSIANS.

2682. The origin of caryatides we have in the First Book (165, *et seq.*) so far as regards our own opinions, explained, and in that respect we shall not trouble the reader. Our object in this section is merely to offer some observations on the use of them in modern practice. The figures denominated Persians, Atlantes, and the like, are in the same category, and we shall not therefore stop to inquire into their respective merits; indeed, that has already been sufficiently done in the book above alluded to. The writer of the article in the *Encyclopedie Methodique* has, we think, thrown away a vast deal of elegant writing on the subject of caryatides; and using, as we have done, to some extent, that extraordinary work, we think it necessary to say that we cannot recommend anything belonging to that article to the notice of the reader, except what is contained in the latter part of it, and with that we do not altogether agree.

2683. The object, or apparent object, in the use of caryatides is for the purpose of support. There is no case in which this cannot be better accomplished by a solid support, such as a column, the use of the attic order, or some other equivalent means. But the variety in quest of which the eye is always in search, and the picturesque effect which may be induced by the employment of caryatides, leads often to their necessary employment. The plain truth is, that they are admissible only as objects necessary for an extreme degree of decoration, and otherwise employed are not to be tolerated. There can, as we imagine, be no doubt that the most successful application of these figures as supports was by Jean Gougeon in the Louvre; as was the most unfortunate in the use of them in a church in the New Road, which at the time of its erection was much lauded, but which we hope will never be imitated by any British architect.

2684. As to the use of what are called Persians or male figures, originally in Persian dresses, to designate, as Vitruvius tells us, the victory over their country by the Greeks, the observations above made equally apply, and in the present day their application will not bear a moment's suspense in consideration.

2685. We have been much amused with the gravity wherewith Sir William Chambers, not with his usual sound sense, treats the claims of the personages whose merits we are discussing: he says, "Male figures may be introduced with propriety in arsenals or galleries of armour, in guard-rooms and other military places, where they should represent the figures of captives, or else of martial virtues; such as strength, valour, wisdom, prudence, fortitude, and the like." He writes more like himself when he says, "There are few nobler thoughts in the remains of antiquity than Inigo Jones's court" (in the design for the great palace at Whitehall), "the effect of which, if properly executed, would have been surprising and great in the highest degree." (See *fig.* 207.)

2686. What is called a *terminus*, which is, in fact, nothing more than a portion of an inverted obelisk, we shall not observe upon further than to say that it is a form, as applied to architecture, held in abhorrence. For the purpose, when detached and isolated, of supporting busts in gardens, it may perhaps be occasionally tolerated: further we have nothing to say in its favour. Those who seek for additional instruction on what are called termini, may find some account of them, as the boundary posts of land among the Romans, in books relating to the antiquities of that people.

2687. We shall now proceed to submit some examples of caryatides for the use of those whose designs require their employment. *Fig.* 926. is from a model of Michael Angelo

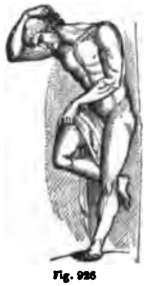

Fig. 926

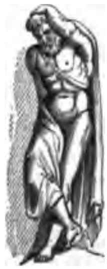

Fig. 927.

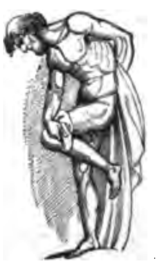

Fig. 928.

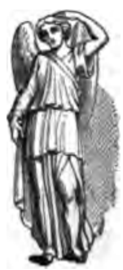

Fig. 929

Buonarotti, and is extracted from the *Treatise on Civil Architecture*, by Sir William Chambers, as are the succeeding examples.

2688. *Figs*. 927. and 928. are also designs by Michael Angelo, which, though not designed for a building, are well adapted for the purpose under certain conditions.

2689. *Fig*. 929. is the design of Andrea Biffi, a sculptor of Milan, in the cathedral of which city it is one of the figures surrounding the choir. The statue possesses much grace, and was admirably suited to the edifice wherein it was employed.

2690. *Fig*. 930. comes from Holland, having been executed by Artus Quellinus in the judgment-hall of the Stadthouse at Amsterdam.

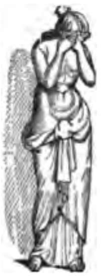

Fig. 930.

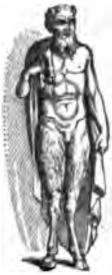

Fig. 931.

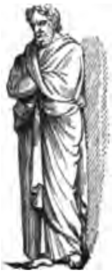

Fig. 932.

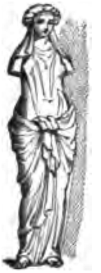

Fig. 933.

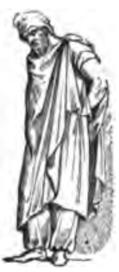

Fig. 934.

2691. *Fig*. 931. is by Michael Angelo, and is at the Villa Ludovisi at Rome.

2692. *Fig*. 932. is from the design by the last-named master for the monument of Pope Julius, whereof we have had occasion already to make mention in the First Book of this work. (362.)

2693. *Fig*. 933. is a representation of one of the celebrated caryatides by Jean Gougeon in the Swiss guard-room of the old Louvre at Paris, and does not deserve less admiration than it has received. The scale on which this and the preceding figures are given does not admit of so good a representation as we could wish.

2694. *Fig*. 934. is from the arch of the goldsmiths at Rome, being thereon in basso rilievo, but considered by Chambers as well as ourselves a suitable hint for carrying out the purpose of this section.

Sect. XVI.

BALUSTRADES AND BALUSTERS.

2695. A baluster is a species of column used as an ornamental railing in front of windows, or in arcades, or on the summit of a building, whose professed object is the protection of its inhabitants from accidents: analogously, too, it consists of a capital, shaft, and base.

2696. The baluster is not found in the works of the ancients, and we believe it owed its introduction in architecture to the restorers of the arts in Italy, in which country a vast variety of examples are to be found. They made their first appearance in the form of stunted columns, not unfrequently surmounted by a clumsily-shaped Ionic capital. The term is said to have had its rise (with what truth we cannot pronounce) from the Latin *balaustium*, or the Greek *βαλαυστιον*, the flower of the wild pomegranate, to which in form the architectural baluster is said by some to bear a resemblance. The writer in the *Encyclopedie Methodique* has taken the opportunity, in the article "Balustre," of launching his anathema against the use of it, but we by no means agree with him; and instead of calling it, as he does, "*une invention mesquine*," we incline to think that it was almost the only invention of the modern architects that deserves our admiration. It is true that the form has been abused in every possible shape; but we are not, in art more than in morals, to arrive at the conclusion that anything is bad because it has been abused and misapplied. Such, then, being the case, we shall proceed in a serious vein to consider its proportions, founded on the best examples that have come to our hands. We must first premise with J. F. Blondel, that balusters and balustrades, which last are a series of the first, should in form and arrangement partake of the character of the edifice. They have even been in their species so subdivided as to be arranged under as many classifications as the orders themselves, a distinct sort having been assigned for employment with each order. We are not quite certain that such an arrangement is necessary, but are rather inclined to think it fanciful; though we are quite willing to allow that where the lighter orders are employed, the balustrades to be used over them are susceptible of a more minute and lighter subdivision of their parts.

2697. The general rules to be observed in the use of the balustrade are, that its balusters be of an odd number, and that the distance between them should be equal to half their larger diameter, from which will result an equality between the open and solid spaces. Blondel disapproves of a half baluster on the flanks of a subdivision of a balustrade: in this we dissent from him, and would always recommend its adoption if possible. In respect of the detailed proportions of the balusters themselves, we are to recollect that the subdivisions are of the capital, the shaft or vase of the baluster, and its base. For proportioning these to one another, Chambers (and we think the proportions he uses not inelegant) divides the whole given height into thirteen equal parts, whereof the height of the baluster is eight, that of the base three, and of the cornice or rail two. If the baluster is required to be less, he divides the height into fourteen parts, giving eight to the baluster, four to the base, and two to the rail. He calls one of these parts a module for the measurement of the rest, and that measure we think convenient for adoption in this work. The module he divides into nine parts.

2698. Balusters intended for real use in a building, as those employed on steps or stairs, or before windows, or to enclose terraces, should not be less than three feet in height, nor more than three feet six inches; that is, sufficiently high to give security to the persons using them: but when merely used as ornamental appendages, as in crowning a building, they should bear some proportion to the parts of the building. Chambers says that their height never ought to exceed four fifths of the height of the entablature on which they are placed, nor should it ever be less than two thirds, without counting the zoccolo or plinth. the height of which must be sufficient to leave the whole balustrade exposed to view from the best point of sight for viewing the building. We can scarcely admit these rules to pass without noting the examples in Palladio's works, which give a much greater latitude for variety. When balusters fill in between the pedestals, as in the façade of the Palace Chiericato at Vicenza, the balustrade's height is of course regulated by that of the pedestal itself; but in the court of the Porti palace the crowning balustrade is not higher than the cornice of the entablature on which it stands. The same proportion is observed in the atrium of the Carità at Venice. In the Valmarana palace the height of the balustrade is equal to that of the entablature of the small order. It is true that in a few instances this master made the height of the balustrade equal to that of the whole entablature, and Inigo Jones has in some instances followed his example; but this was not the general practice either of the one or the other.

2699. We have already said that the baluster generally varies in form, so as to be appropriate to the order over which it is used. It is moreover to be observed that the baluster is susceptible of a pleasing variety of its form by making it square instead of circular on the plan, whereof examples are given in *figs.* 938, 939, and 940.; but when the situation requires an expression of solidity, almost all the circular examples we submit to the reader may be changed from a circular to a square form on the plan, and thus as required we may obtain the character suitable to their respective situations. These changes, from one to another form in details of this description, are in their adoption much more the index to the capacity and genius of the architect than the restless and capricious longing after variety recently exhibited in some of the latest works produced in the city of London, works which reflect no credit on the age in which we live. In *fig.* 935. is given a baluster suitable to the Tuscan order; and using the module of nine parts above mentioned, the following is a table of its dimensions:—

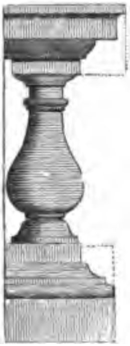
Fig. 935.

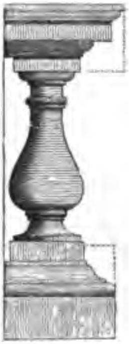
Fig. 936.

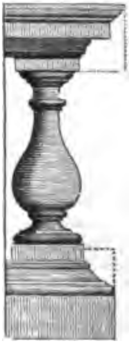
Fig. 937.

Members.		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Rail, 2 modules.	Fillet	3	27½
	Corona	8⅔	24⅓
	Quarter round	4⅔	
	Fillet	1⅔	
Baluster, 8 modules.	Abacus	5⅔	11½
	Cyma reversa	4	
	Neck	5	5¼
	Astragal Fillet	3⅓	
	Centre of belly	27	13
	From same to astragal	9	
	Astragal Fillet	2⅓	10⅓ fillet
	Inverted cyma	6⅓	
	Plinth	7⅓	13
Pedestal, 3 modules.	Inverted cavetto	5	
	Fillet	2	
	Astragal	5	
	Plinth	15	24

2700. In *fig.* 936. is given the form of a baluster suited to the Doric and Ionic orders, of which also the table of dimensions is subjoined: —

Members.		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Rail, 2 modules.	Fillet	2	27
	Cyma reversa	3⅔	
	Corona	7	22
	Quarter round	4	
	Fillet	1⅓	
Baluster, 8 modules.	Abacus	5⅔	11
	Echinus	3⅓	
	Fillet	1	
	Neck	5	5
	Astragal Fillet	3	
	Centre of belly	27	12⅓
	From same to astragal	9	
	Astragal	2	
	Fillet	1	
	Inverted cavetto	6	10 (upper part)
	Fillet	2⅔	
	Plinth	7⅓	12⅓
Pedestal, 3 modules.	Fillet	1⅓	
	Inverted ogee	5	
	Fillet	1⅔	
	Astragal	4⅓	
	Plinth	15	23⅓

2701. A suitable baluster for the Corinthian or Composite order is exhibited in *fig.* 937., whereof the measures are as follow: —

Members.		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Rail, 2 modules.	Fillet	1⅔	26½
	Echinus	2⅔	
	Fillet	1	
	Corona	6⅓	21½
	Cyma reversa	3⅔	
	Astragal Fillet	2⅔	
Baluster, 8 modules.	Abacus	5	10½
	Echinus	3	
	Fillet Cavetto	2⅓	
	Neck	5	4¾
	Astragal Fillet	2⅔	
	Centre of belly	27	12
	From same to astragal	9	
	Astragal Fillet	2⅔	
	Scotia	4⅔	4¾ (at top)
	Fillet	1	
	Astragal	3⅔	
	Plinth	6	12
Pedestal, 3 modules.	Fillet Astragal	2⅔	
	Inverted cyma recta	4⅓	
	Fillet	1	
	Astragal	4	
	Plinth	15	23

2702. The Tuscan baluster (*fig.* 938.) is suitable for terraces and basements: its rail and pedestal may be the same height as in the *fig.* 935. Its principal measures being as follow: —

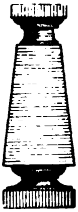
Fig. 938.

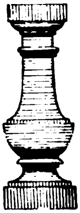
Fig. 939.

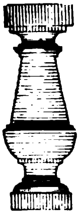
Fig. 940.

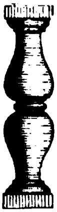
Fig. 941.

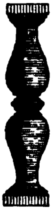
Fig. 942.

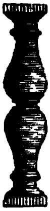
Fig. 943.

Members		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Baluster 5 modules.	Abacus	3	6
	Cyma reversa	2	
	Neck Fillet	4	3
	Rustic belly at top	- -	4½
	Rustic belly	27	
	Rustic belly at bottom	- -	7½
	Bottom of belly Fillet	2½	
	Inverted cavetto and fillet	3	3
	Plinth	3½	7½

Other forms of Tuscan balusters are given in *figs.* 939. and 940., but it is not necessary to give the detail of the parts, as the proportions are sufficiently preserved in the figures.

2703. The double-bellied baluster is used in situations where greater lightness is required from the smallness of the parts and the delicacy of the profiles. The proportions for the bases and rails need not vary from those already given. Perhaps they need not be quite so large.

2704. *Fig.* 941. is an example of a double-bellied baluster, suitable to the Doric order. Its parts are as follow: —

Members.		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Baluster, 8 modules.	Abacus	4½	8
	Echinus Fillet	4½	
	Upper part	24¾	4 neck 8 belly
	Middle part	4½	6 centre
	Lower part	24¾	8 belly 4 neck
	Fillet Inverted echinus	4½	
	Plinth	4½	8

2705. In *fig.* 942. we give an example of the double-bellied baluster for the Ionic order, and its measures are subjoined: —

Members.		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Baluster, 10 modules.	Abacus	4½	9
	Fillet and cyma reversa	4½	
	Upper part	30½	4½ neck 9 belly
	Middle part	9	7½ centre
	Lower part	30½	9 belly 4½ neck
	Inverted cyma and fillet	4½	
	Plinth	4½	9

2706. The last example we shall give of the double-bellied baluster (*fig.* 943.) is suitable to the Corinthian order. The measures are as follow: —

Members.		Heights in Parts of a Module.	Projections in Parts of a Module from Centre of Baluster.
Baluster, 12 modules.	Abacus	5	11
	Echinus and fillet	4	
	Neck	5½	5½
	Astragal and fillet	3½	
	Upper part	29	5½ at top 11 at belly
	Middle	6	
	Lower part	29	11 at belly 5½ at bottom
	Fillet and astragal	3½	
	Neck	5½	5½
	Fillet and inverted echinus	4	
	Plinth	5	11

2707. We do not deem it necessary to give any examples of the scroll and Guilloche balustrades, which were so much in vogue during the reigns of Louis XIV. and Louis XV., though the present taste seems almost to require it. As that taste has been mainly generated by house decorators, as they are called, and upholsterers, these gentry will soon find out another means of amusing the public, by driving them out of fashion and finding all that is beautiful in some renovated and equal absurdities.

2708. We have already observed that the intervals between balusters should not be more than half the diameter of the baluster at its thickest part; to this we may here add, that they should not be less than one third of that diameter. The pedestals for supporting the rail ought neither to be too frequent nor too far apart; for in the first case they impart a heavy appearance to the work, and in the last the work will seem weak. Seven or nine balusters are good numbers for a group, besides the two half ones engaged in the pedestals. The disposition, however, and number of the pedestals depend on the places below of the piers, columns, or pilasters, for over these a pedestal must stand; and when, therefore, it happens that the intervals are greater than are required for the reception of nine balusters, the distance may contain two or three groups each, flanked with half balusters, and the width of the dies separating the groups may be from two thirds to three quarters the width of the principal pedestals. The rail and base should not be broken by projections, but run in unbroken lines between the pedestals.

2709. When the principal pedestals stand over columns or pilasters, their dies should not be made wider than the top of the shafts, and on no account narrower; indeed, it is better to flank them on each side when the ranges are long with half dies, and give a small projection to the central pedestal, and to let the base and rail follow the projection in their profiles. This practice will give real as well as apparent solidity to the balustrade.

2710. *Fig.* 944. shows the application of a balustrade to a portion of a staircase, and herein the same proportions are observed as on level ranges. Some masters have made the mouldings of the different members of the baluster, follow the *rake* or inclination of the steps; but the practice is vicious: they should preserve their horizontality, as exhibited in the figure, in which, at A and B, is also shown the method in which the horizontal are joined to the inclined mouldings of the base and rail. In the balustrades of stairs the spaces between the balusters are usually made narrower than they are on level beds; and Le Clerc recommends that the height of the plinth should be equal to that of the steps; but this is not absolutely required, though it must on no account be less.

2711. The bulbs or bellies of balusters and their mouldings may be carved and otherwise enriched: indeed, in highly decorated interiors, this seems requisite.

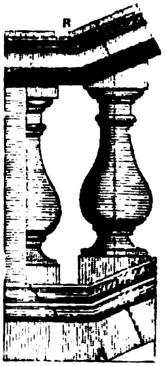

Fig. 944.

2712. The following observations as to the height of statues placed upon balustrades are from Sir William Chambers: — "When statues are placed upon a balustrade their height should not exceed one quarter of the column and entablature on which the balustrade stands. Their attitudes must be upright, or, if anything, bending a little forwards, but never inclined to either side. Their legs must be close to each other, and the draperies close to their bodies, for whenever they stand straddling with bodies tortured into a variety of bends, and draperies waving in the wind, as those placed on the colonnades of St. Peter's, they have a most disagreeable effect, especially at a distance, from whence they appear like lumps of unformed materials, ready to drop upon the heads of passengers. The three figures placed on the pediment of Lord Spencer's house, in the Green Park, which were executed by the late ingenious Mr. Spang, are well composed for the purpose."

2713. "The heights of vases placed upon balustrades should not exceed two thirds of the height given to statues," says the same author. We are not altogether averse to the application of either statues or vases in the predicated situations, but we think the greatest discretion is required in their employment. When it is necessary to attract the eye from an indispensably obtrusive roof, they are of great value in the composition; but we shall not further enter on this point of controversy, for such it is, inasmuch as many object to their use altogether, and have considerable reason on their side. We must, however, briefly state the ground of objection, and Chambers's answer as respects statues. There are, he says, some "who totally reject the practice of placing statues on the outsides of buildings, founding their doctrine, probably, upon a remark which I have somewhere met with in a French author, importing that neither men, nor even angels or demi-gods, could stand in all weathers upon the tops of houses or churches."

2714. "The observation is wise, no doubt," (we doubt the wisdom of it,) "yet, as a piece of marble or stone is not likely to be mistaken for a live demi-god, and as statues, when properly introduced, are by far the most graceful terminations of a composition, one of the most abundant sources of varied entertainment, and amongst the richest, most durable, and elegant ornaments of a structure, it may be hoped they will still continue to be tolerated." We fear that if the only reasons for their toleration were those assigned by the author, their doom would soon be sealed.

SECT. XVII.

PEDIMENTS.

2715. A pediment, whose etymology is not quite clear, but which in the glossary appended has been conjectured, consists of a portion of the horizontal cornice of the building to which it is applied, meeting two entire continued raking cornices, and enclosing by the three boundaries a space which is usually plain, called the *tympanum*. It is not, however, necessary that the upper cornice should be rectilinear, inasmuch as the cornice is sometimes formed by the segment of a circle. The arrangement in question was the Roman *fastigium*, and is the French *fronton*. The Greeks called pediments *αετοι*, or eagles; why, this is not the place to inquire. The origin of the pediment, according to authors, seems to have arisen from the inclined sides of the primitive hut. This is a subject, however, which in the First Book (subsec. 5.) has been already considered, and we shall therefore in this section confine ourselves to its employment in the architecture of the day.

2716. Of the varied forms which, by masters even of acknowledged talent, have been given to the pediment, whether polygonal, with curves of contrary flexure, with mixed forms, broken in the horizontal part of the cornice or in the raking parts of it, or reversed in its office with two springing inclined sides from the centre, we propose to say no more than that they are such abuses of all rules of propriety, that we shall not further notice them than by observing that in regular architecture no practice is to be tolerated where the pediment is composed otherwise than of two raking unbroken and one horizontal unbroken cornice, or of the latter and one continued flexure of curved line. To these only, therefore, we now apply ourselves.

2717. Generally, except for windows and doors, the pediment ought not to be used, except for a termination of the whole composition; and though examples are to be found without number in which an opposite practice has obtained, the reader, on reflection, will be convinced of the impropriety of it, if there be the smallest foundation for its origin in the termination of the slant sides of the hut.

2718. The use of the pediment in the interior of a building is, perhaps, very questionable, though the greatest masters have used it. We think it altogether unnecessary; if the pyramidal form is desirable for any particular combination of lines, it may be obtained by a vast number of other means than that of the introduction of the pediment. Hence we are of opinion that the attempted apology for them in Sir William Chambers's work, is altogether weak and unworthy of him, and only to be explained by that master's own practice.

2719. Vitruvius ordains that neither the modillions nor dentils which are used in the horizontal cornice should be used in the sloping cornices of a pediment, inasmuch as they represent parts in a roof which could not appear in that position: and the remains generally of antiquity seem to bear him out in the assertion; but the Roman remains seem to bear a different testimony to the validity of the law, and to our own eyes the transgression affords pleasure, and we should recommend the student not to feel himself at all bound by it; for, as Chambers most truly observes, "The disparity of figure and enrichment between the horizontal and inclined cornices are such defects as cannot be compensated by any degree of propriety whatever, and therefore to me it appears best, in imitation of the greatest Roman and modern architects, always to make the two cornices of the same profile, thus committing a trifling impropriety to avoid a very considerable deformity."

2720. Different sized pediments in the same façade are to be avoided; but as respects their forms in ranges of windows and niches a pleasing variety is often obtained by making them alternately curved and rectilinear, as in the temple at Nismes and in the niches of the Pantheon at Rome.

2721. In the horizontal part of a cornice under a pediment the two upper mouldings are always omitted, and the intersection of the inclined with the horizontal lines, supposing the inclined members of the cornice to be of the same height as those which are horizontal, will not fall into the profile (*fig.* 945.) whereof AB and BC are the leading lines. To obviate this inconvenience, some architects have made a break in the cymatium and fillet, as shown

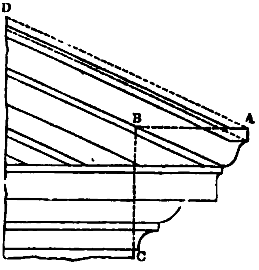

Fig. 945.

in the figure. But this is a bad practice, and to it we prefer either making the cyma and fillet higher, as the dotted line AD indicates, or altogether lowering the height of the cyma on the horizontal line. If the inclined cornice is joined on each side by horizontal ones, the best expedient is to give only such small projection to the cyma as that it may meet the inclined sides.

2722. The heights of pediments should be regulated by their lengths, independent of the consideration of climate. (See Book II. Chap. III. Sect. IV. 2027.) Thus, when the base of the pediment is short, the height of the pediment may be greater; and when long, it should be diminished; for in the former case the inclined cornice leaves but scanty space for the tympanum, and in the latter case the tympanum will appear overcharged. From one fifth to one quarter of the length appears to have been agreed on as the limits; but we subjoin, from a work by Stanislas L'Eveillé (*Considérations sur les Frontons*, 4to. Paris, 1824), the method which we consider the best for determining the height of a pediment, observing, by the way, that a strict adherence to the ordinary rules for finding the height may produce the absurdity of a pediment higher than the columns by which it is borne, a condition which would not at all accord with the view we have taken of the orders in Sect. II. Chap. I. of this Book. In fig. 946. we have a synoptical view of pediments of various extents, and as the letters applied to the central pediment will apply to all the rest, we shall restrict our description to that. Suppose the points *a* and *b* to be the extremities of the fillet of the corona. Then, with a radius equal to *ab*, from the points *a* and *b*, describe the arcs *ax*, *bx*, and from their intersection *x* with the same radius let the arc *ayb* be described. From *y*, as a centre, with a radius equal to the height of the horizontal part of the cornice, describe the portion of the circle *fg*, and from *a* and *b* draw thereto tangents intersecting in *y*. Then *yb* and *ya* will be the proper inclination of the fillet of the corona to which the other members of the inclined parts will necessarily be parallel.

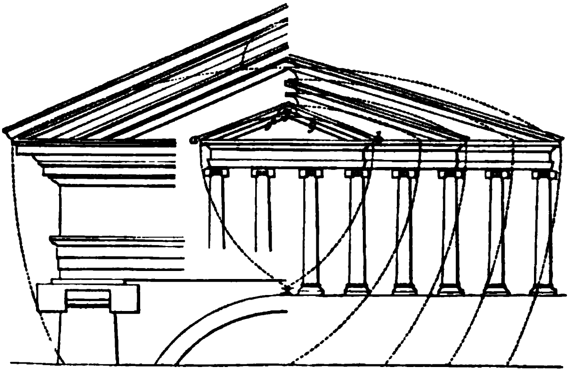

Fig. 946.

2723. We conclude this section by the words of Chambers. "The face of the tympan is always placed on a line perpendicular with the face of the frieze; and when large, may be adorned with sculpture, representing the arms or cypher of the owner, trophies of various kinds, suited to the nature of the structure, or bas-reliefs, representing either allegorical or historical subjects; but when small it is much better left plain."

Sect. XVIII.

CORNICES.

2724. In many cases the façades of buildings are erected without any of the orders appearing in the design, other, perhaps, than those which are applied as the dressings of windows, niches, or doors. The palaces of Florence and Rome abound with such examples, in most of which the edifice is crowned with a cornice, which adds dignity to the building, producing a play of light and shadow about it of the utmost importance as regards its picturesque effect. The moderns have generally failed in this fine feature of a building, and it is only within the last few years, in this country, that a return to the practice of the old masters, a practice properly appreciated by Jones, Wren, Vanbrugh, and Burlington, has manifested itself. If a building be entirely denuded of pilasters and columns, and there are very few common instances that justify their introduction, it seems rational to deduce the proportion of the height and profile of its cornice from the proportions that would be given to it if an order intervened.

2725. If we consider the height of the crowning cornice of a building in this way, and as the portion of an entablature whose height is, as in the case of an order, one fifth of that of the building, we should immediately obtain a good proportion by dividing the whole height into 25 parts and giving two of them to the height of the cornice. For the entablature being one fifth of the whole height, and its general division being into 10 parts, four whereof are given to the cornice, we have for its height the $\frac{4}{10}$ of $\frac{1}{5}=\frac{4}{50}$ $=\frac{2}{25}$, or the twelfth and a half part of the total height of the building $=0{\cdot}08$. Now there are circumstances, such as when the piers are large, and in other cases when the parts are not very full in their profiles, which may justify a departure from the strict application of this rule; but it will be seen that in the following ten well-known examples the practice has not much differed from the theory, the greatest deviation being in the celebrated cornice of the Farnese palace, which is here placed (*fig.* 947.) as an extraordinary work of art in connection with the building it crowns. The examples alluded to are as follow, and we shall begin with those of earlier date, the diminution in height being almost a chronological table of their erection, with the exception of those by Palladio: —

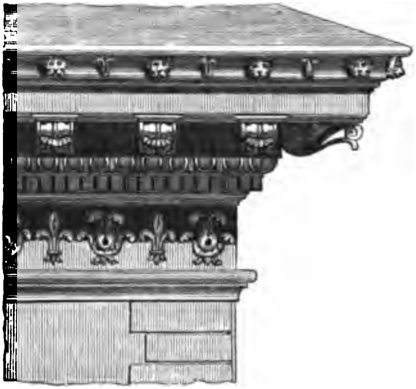

Fig. 947.

In the Spannocchi palace, at Siena, the cornice is $\frac{81}{1000}$ of the whole height of building, or $\frac{2}{27}={\cdot}081$.

In the Picolomini palace, at Siena, the cornice is $\frac{74}{1000}$ of the whole height of building, or $\frac{2}{27}={\cdot}074$.

In the Pojana palace, built by Palladio, at Pojana, in the Vicentine territory, the cornice is $\frac{71}{1000}$ of the whole height of building, or $\frac{1}{14}=071$.

In the Strozzi palace, at Florence, the cornice is $\frac{69}{1000}$ of the whole height of building, or $\frac{2}{29}={\cdot}069$.

In the Pandolfini palace, at Florence, by Raffaelle, the cornice is $\frac{69}{1000}$ of the whole height of building, or $\frac{2}{29}={\cdot}069$.

In the Villa Montecchio, by Palladio, the cornice is $\frac{69}{1000}$ of the whole height of building, or $\frac{2}{29}={\cdot}069$.

In the Villa Caldogno, by Palladio, the cornice is $\frac{69}{1000}$ of the whole height of building, or $\frac{2}{29}={\cdot}069$.

In another villa by Palladio, for the family of Caldogno, the cornice is $\frac{66}{1000}$ of the whole height of building, or $\frac{1}{15}={\cdot}066$.

In the Farnese palace, at Rome, the cornice is $\frac{59}{1000}$ of the whole height of building, or $\frac{1}{17}$ $={\cdot}059$.

In the Gondi palace, at Florence, the cornice is $\frac{57}{1000}$ of the whole height of building, or $\frac{2}{35}$ $={\cdot}057$.

From these examples it appears that the mean height of the cornices under consideration is something more than one fifteenth of the height of the building, and experience shows that, except under particular circumstances, much more than that is too great, and much less too little, to satisfy an educated eye. The grace beyond the reach of art is, if we may use an Hibernicism, in the power of few, but the bounds have been passed with success, as is testified in the Farnese palace. It may be objected to the system that we have generally adopted in this work, that we are too much reducing the art to rules. But this is a practice of which the painter is not ashamed in the proportions of the human figure, and we must remind our reader and the student that all rules are more for the purpose of restraining excess than bounding the flights of genius.

2726. *Fig.* 948. is an entablature by Vignola, which possesses great beauty, and has been often imitated in various ways for crowning a building; this must be con-

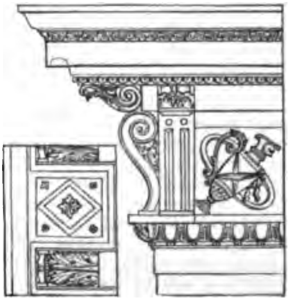

Fig. 948.

sidered more in relation to a building than a mere cornice, and requires rustic quoins, if possible, at the angles when used. Chambers, speaking of this example, says, that "when it is used to finish a plain building, the whole height is found by dividing the height of the whole front into eleven parts, one of which must be given to the entablature, and the remaining ten to the rest of the front." We suspect that the smallness which is assigned by this author to its height has been induced by some error, and that a better rule would be induced by assigning to the cornice its proper height, according to the laws above hinted at, and proportioning the rest of the entablature from the cornice thus obtained.

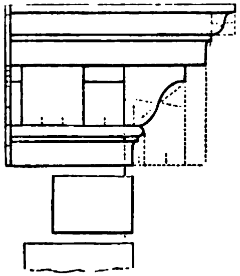
Fig. 951.

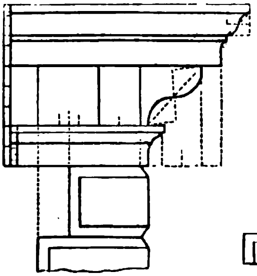
Fig. 950.

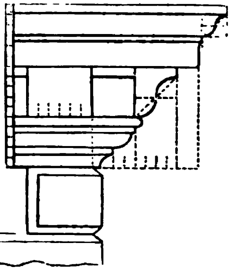
Fig. 949.

2727. In *figs.* 949, 950, and 951. are given three examples of block cornices (the second being by Palladio), whose proportions the figures sufficiently show without here giving a detail of their parts. The height of either should not be less than one fifteenth of the height of the building.

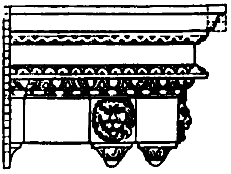
Fig. 952.

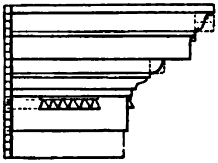
Fig. 954.

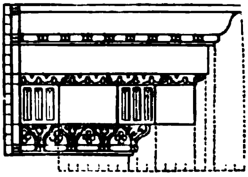
Fig. 953.

2728. *Figs.* 952. and 953. are block cornices, which we have adopted from Chambers, the first being from a palace at Milan, and the other, by Raffaelle, in a house in the Lungara at Rome. The height of these, says the author, and we agree with him, need not exceed one sixteenth part of the whole front, nor should either be less than one eighteenth. *Fig.* 954. is what is called an architrave cornice, which was frequently employed by the old masters. It seems well adapted to the entablatures of columns bearing arches, being rather in the nature of an impost; but it is useful, changing it to suit the order in cases where the height does not admit of the whole of the entablature being used over the order.

Sect. XIX.

PROFILES OF DOORS.

2729. One of our objects in this work has been to impress throughout on the minds of our readers that architecture does not depend on arbitrary laws; and though we may not have proved satisfactorily to the student that the precise laws have been exactly stated, we trust we have exhibited sufficient to show and convince him that there was a method and limit in the works of the ancients which in the best times prevented the artists from falling on either side into excess.

2730. In *fig.* 955. we give a door with its architrave, frieze, and cornice, without relation to mouldings, but merely considered in the masses. Its proportions correspond with those most usually adopted; that is, its height is twice its width, the entablature is one fourth of the height of the opening, and the architraves on each side, together, two sixths of the width. The opening, therefore, measuring it in terms of the width of the architrave, will be 6 parts wide and 12 high, and its area consequently 72 parts. Now

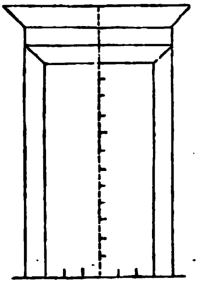

Fig. 255.

it will be found that the solid parts of this are exactly on their face two thirds of this area; for up to the top of the opening each architrave being equal to 12, the sum will be 24; and the entablature being 8 wide and 3 (one fourth of twelve) high, $8 \times 3 = 24$; which added to 24 for the architraves gives 48 for the solids, and $\frac{48}{72} = \frac{2}{3}$, as above stated. The same analogy does not seem to hold in respect of doors and windows, of making the voids equal to the supports and weights, as in intercolumniations; nor indeed ought we to expect to find it, for the conditions are totally different, inasmuch as no door can exist except in a wall, whereas the office of columns is connected with the weight above only. We trust, therefore, we have shown enough to keep the reader's mind alive to some such law as above developed, without insisting very strongly on a minute attention to it in detail.

2731. We shall now, before submitting any examples of doorways to the reader, touch upon some important points that must be attended to; the first of which is, that all gates and doors, independent of all other considerations, must be of sufficient size for convenient passage through them. Hence internal doors must never be reduced under 2 feet 9 or 10 inches, and their height must not be under 6 feet 10 inches or 7 feet, so as to admit the tallest person to pass with his hat. There are minimum dimensions for ordinary houses in the principal floors; but for houses of a superior class, which are provided with what may be called state apartments, widths of 4, 5, and 6 feet, folding doors and the like, will not be too great for the openings, and the heights will of course be in proportion. The entrance doors of private houses ought not to be under 3 feet 6 inches, nor ordinarily more than 6 feet in width; but in public buildings, where crowds of people assemble, the minimum width should be 6 feet, and thence upwards to 10 or 12 feet. No gate should be less than 9 feet wide; and when loaded waggons or carts are to pass through it, 11 or 12 feet will not be too much. As a general observation we may mention that all doors should open inwards, for otherwise the person entering pulls the door in his face, which is an inconvenient mode of entering a room. Also when the width of a door is greater than 3 feet 8 inches it should be formed in two flaps, by which three advantages accrue: first, that the door will not occupy so much space for opening; second, that each door will be lighter; and, third, that the flaps will more nearly fold into the thickness of the wall. Chambers properly says, "That in settling the dimensions of apertures of doors regard must be had to the architecture with which the door is surrounded. If it be placed in the intercolumniation of an order, the height of the aperture should never exceed three quarters of the space between the pavement and the architrave of the order; otherwise there cannot be room for the ornaments of the door. Nor should it ever be much less than two thirds of that space, for then there will be room sufficient to introduce both an entablature and a pediment without crowding; whereas if it be less it will appear trifling, and the intercolumniation will not be sufficiently filled. The apertures of doors placed in arches are regulated by the imposts, the top of the cornice being generally made to level with the top of the impost; and when doors are placed in the same line with windows, the top of the aperture should level with the tops of the apertures of the windows; or if that be not practicable without making the door much larger than is necessary, the aperture may be lower than those of the windows, and the tops of all the cornices made on the same level."

2732. To say that the principal door of a building should if possible be in the centre of the front would seem almost unnecessary; but it is not so, perhaps, to inculcate the necessity of its being so situated in connection with the internal arrangement of the building as to lead with facility to every part of it, being, as Scamozzi observes (Parte Secunda, lib. vi. c. 4.), like the mouth of an animal placed in the middle of the face, and of easy communication with the *inside*. In the internal distribution the doors should as much as possible be opposite one another on many accounts, not the least whereof is the facility thus given to ventilation; but such a disposition also gives the opportunity of a far better display of a series of rooms, which on occasions of fêtes imparts great magnificence to the apartments. In this climate it is well to avoid too great a number of doors, and they should never, if it can be avoided, be placed near chimneys, because of subjecting to draughts of air those who sit near the fire. Generally the doors in a room should be reduced to the smallest number that will suit the distribution, and the practice of making feigned or blank doors, though sometimes necessary, should if possible be excluded.

2733. The ornaments with which doors are decorated must of course depend on the building in which they are used; and as this is a matter in which common sense must direct the architect, it is hardly necessary to say that the ornaments applied to them in a theatre would ill suit a church.

2734. The composition and designing of gates and their piers must of necessity suit the occasion, as well as the folding gates attached to them, for the enclosure of the parks, gardens, and other places they are to serve. There are few finer examples in the higher class of this species of design than the celebrated gates at Hampton Court.

2735. The evil days on which we have fallen in this country, in respect of the arts, precludes the hope of again seeing the doors of our buildings ornamented with bassi relievi and bronze ornaments, a practice common among the ancients no less than among the revivers of the arts; witness the doors of St. Peter's, and, above all, those monuments of the art, the doors of the baptistery at Florence by Lorenzo Ghiberti, wherein art rises by being made only subservient to the holy purpose to which it is the mere handmaid. In the mention of doors those of San Giovanni Laterano at Rome must not be omitted; they have the credit of having been the enclosures to the temple of Saturn in the ancient city.

2736. The manufacture of doors has been already sufficiently noticed in the Second Book; and it therefore only remains for us to subjoin a few examples, which, we think, among many others, deserve the attention of the student.

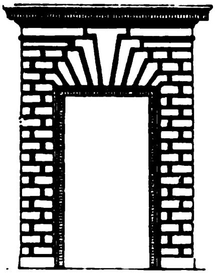
Fig. 957.

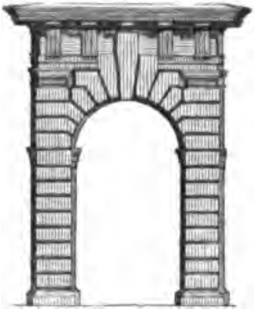
Fig. 956.

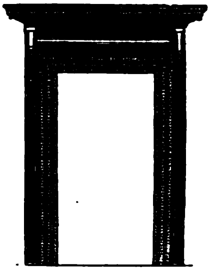
Fig. 958.

2737. Fig. 956. is an external doorway designed and executed by Vignola, at Caprarola, not a great distance north of Rome; it must speak for itself: if the reader be of our mind, he will see in it a beautiful handling of the subject; but we cannot further answer for our opinion, knowing as we do that some of the reviewers of these days may find out that it possesses no *æsthetic* beauties. There are cases where imitation has been permitted; and the sanction for our opinion is, that it has been imitated by one whom we and all others hold in reverence at Greenwich Hospital, though, as we think with Chambers, for the worse. "The aperture is in the form of an arch, and occupies somewhat more than two thirds of the whole height. It is adorned with two rusticated Doric pilasters and a regular entablature. The height of the pilasters is 16 modules, that of the entablature 4. The width of the aperture is 7 modules, its height 14, and the breath of each pier is 3 modules." To the detail of Chambers we have to add that the void in this example, which has no analogy to that which as a general rule we gave in the commencement of the section, is about one third of the area of the whole design, the void being to such area as 7·57 to 20·88.

2738. *Fig.* 957. is a design by the last-mentioned master, in which the void is as nearly as possible equal to one third of the area, the supports another, and the weights the other third: in other terms, the aperture occupies two thirds of the whole height and one half of the whole breadth, being, in fact, a double square. Its entablature has an alliance with the Tuscan order, and the cornice is equal to one fifteenth of the whole height of the door. These two examples are especially external; those which follow are from their nature applicable in general form to either external or internal doorways.

2739 *Fig.* 958. is a doorway in the Cancellaria at Rome, and is from the design of Vignola. The width is one half the height, and the height of the entablature is equal to one third of the height of the aperture. The breadth of the architrave is one fifth of the aperture's width, and the pilasters below the consoles are half as broad as the architrave. It is heavy, as might have been expected from the proportion between the voids and the solids.

2740. *Fig.* 959. is a design by Michael Angelo Buonarotti, and its aperture may be twice its height,

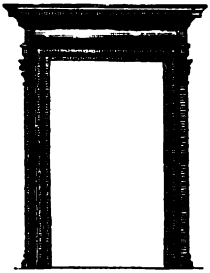
Fig. 959.

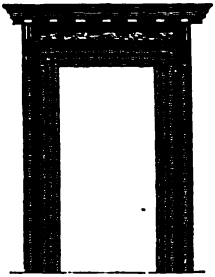
Fig. 9 0.

the whole entablature a quarter of its height, and the architrave one sixth of the width of the aperture. The face of the pilasters or columns at the sides must be regulated by the lower fascia of the architrave, and their breadth is to be a semidiameter.

2741. *Fig.* 960. is by Vignola, and is in the Farnese palace at Rome. The opening is twice the width in height, and the entablature is three elevenths of the height of the aperture, one of the foregoing elevenths being given to the architrave. The whole of the ornament on the sides is, including architraves and pilasters, equal to two sevenths of the width of the aperture. The cornice is Composite, with modillions and dentils, and the frieze is enriched with a laurel band.

2742. *Fig.* 961., another of the examples given by Chambers, is believed to be by Cigoli. The void is rather more in height than twice its width. The impost of the arch is equal to half a diameter, the columns are rather more than nine diameters high, and rusticated with five square cinctures. The entablature is not so much as one quarter of the height of the column, and its tablet is equal to the width of the aperture.

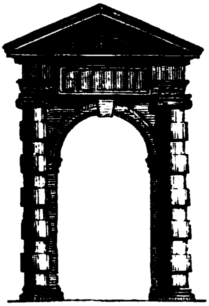

Fig. 961.

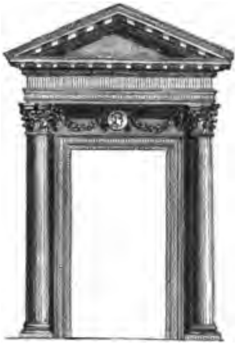

Fig. 962.

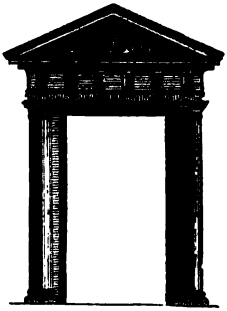

Fig. 963.

2743. *Fig.* 962. is by Inigo Jones, and the aperture may be twice as high as it is wide. The architrave may be a sixth or seventh of the width of the aperture, the top of it being level with the astragal of the columns, which are Corinthian, and ten diameters in height. They must be so far removed on each side from the architrave as to allow the full projection of their bases. The entablature may be from two ninths to one fifth of the column, and the pediment should be regulated by the rules given in Sect. XVII. (2722.).

2744. *Fig.* 963. is by Serlio. The aperture may be a double square, or a trifle less; the diameter of the columns a quarter of the width of the aperture, or a trifle less; their height 8 to 8½ diameters; the entablature about a quarter of the height of the columns, and the pediment should be drawn in conformity with the directions in Sect. XVII.

Sect. XX.

WINDOWS.

2745. Windows, of all the parts of a building, are those which require the greatest nicety in adjustment between the interior and exterior relations of them. The architect who merely looks to the effect they will produce in his façades has done less than half his work, and deserves no better name or rank than that of a mere builder. It seems almost useless to observe that the windows of a building should preserve the same character, that those in each story must be of the same height, and that the openings must be directly over one another. Blank windows are, if possible, to be avoided; they always indicate that the architect wanted skill to unite the internal wants of the building with its external decoration. Windows, moreover, should be as far removed as the interior will permit from the quoins of a building, because they not only apparently, but really, weaken the angles when placed too near them.

2746. Vitruvius, Palladio, Scamozzi, and Philibert de l'Orme, besides many other masters, have given different proportions to them as connected with the apartments to be lighted. That these should be different is indicated by the different places in which those masters have written. Nothing, indeed, seems so much to disallow general laws as the proportion of windows to an apartment; according to the climate, the temperature, the length of the days, the general clearness of the sky, the wants and customs of commerce and of life generally. In hot climates the windows are always few in number and small in dimension. As we approach those regions where the sun has less power and the winter is longer, we observe always an increase in their size and number, so as to enable the inhabitants to take as much advantage as possible of the sun's light and rays. It seems, therefore, almost impossible to give general rules on this subject. We shall on this account endeavour, in the rules that this section contains, to confine ourselves to the sizes which seem suitable in this climate, as respects the proportion of light necessary for the comfort of an apartment.

2747. It is a matter of experience that the greatest quantity of light is obtained for an apartment when lighted by an horizontal aperture in the ceiling. Of this a very extraordinary verification is to be found in the Pantheon at Rome. This edifice, whose clear internal diameter is 142 feet 6 inches, not including the recesses behind the columns, is nearly 74 feet high to the springing of the dome, which is semicircular. The total clear number of cubic feet in it may therefore be taken in round numbers at 1,934,460 cubic feet. Those who have visited it well know that it is most sufficiently and pleasingly lighted, and this is effected by an aperture (the *eye*, as it is technically called,) in the crown of the dome, which aperture is only 27 feet in diameter. Now the area of a circle 27 feet in diameter being rather more than 572 feet, it follows that each superficial foot of the area lights the astonishing quantity of nearly 3380 cubic feet. Independent of all considerations of climate, this shows the amazing superiority of a light falling vertically, where it can be introduced. But in a majority of cases the apertures for light are introduced in vertical walls; and the consequence is, that a far greater area of them for the admission of light becomes necessary. In considering the question it must be premised that a large open space is supposed before the windows, and not the obstructed light which it is the lot of the inhabitants of closely-built streets to enjoy. Again, it is to be recollected that in the proportioning of windows it is the apartments on the principal floor that are to be considered, because their width in all the stories must be guided by them, the only variety admissible being in the height. In this country, where the gloom and even darkness of wet, cloudy, and foggy seasons so much prevails, it is better to err on the side of too much rather than too little light, and when it is superabundant to exclude it by means of shutters and blinds. We are not very friendly to the splaying of windows, because of the irregularity of the lines which follows the practice; but, it must be admitted, it often becomes necessary when the walls are thick, and in such cases a considerable splay on the inside increases the light in effect by a great diminution of shade. It is well, if possible, to have an odd number of windows in an apartment: nothing wherein contributes more to gloom than a pier in the centre.

2748. We do not think it necessary to advert to the rule of Palladio for the dimensions of windows given in the first book of his work, chap. 25.; because, were it true for the climate of northern Italy, it would not be so for that of Great Britain; neither are we at all satisfied with that which in his practice Sir William Chambers says he adopted, and which is as follows, in his own words:—"I have generally added the depth and height" we suppose width "of the rooms on the principal floor together, and taken one eighth part thereof for the width of the window; a rule to which there are few objections: admitting somewhat more light than Palladio's, it is, I apprehend, fitter for our climate than his rule would be." This rule is empirical, as indeed is that on which we place most dependence, and to which we shall presently introduce the reader, being ourselves inclined to the belief that in the lighting a room there is a direct relation between the area of the aperture admitting the light and the quantity of cube space in the room. Indeed the law which we are about to give is one founded on the cubic contents of the apartment; and if the results bore a regular ratio to that quantity, the discussion would be at an end, for we should then have only to ascertain the cubic contents, and, knowing how much an area of light one foot square would illuminate, the division of one by the other would supply the superficies of windows to be provided. Our own notion on this subject is, that 1 foot superficial of light in a vertical wall, supposing the building free from obstruction by high objects in the neighbourhood, will in a square room be sufficient for 100 cube feet if placed centrally in such room. It will, however, immediately occur to the reader, that this rule cannot in many cases satisfy the requirements of an apartment as respects the quantity of light necessary for its proper illumination. The subject is beset with numerous difficulties, which to overcome requires the greatest skill. In the case of an apartment, long as compared with its width, it is well known to every practical architect that windows of the same collective area at either of the narrow ends of such apartment will light it much more effectively than if the same area of light were admitted on either of the long sides, and most especially so, if it should happen that on such long side there were a pier instead of a window in the centre of such side. In illustration of what we mean, let us refer the reader to the ball room at Windsor Castle, an apartment 90 feet long, 34 feet wide, and 33 feet high. This room is lighted from the northern narrower side by a window nearly occupying the width, and is supplied by an abundance of light. But had the same quantity of light been admitted from either of the long sides of the room, so many masses of shadow would have been introduced through the interposition of piers, that its effect would have differed most widely from the cheerful and airy aspect it now presents. We have taken this as an example that more presently occurs to us, but the reader from his observation will have no difficulty in supplying instances in corroboration of our impressions on this subject.

But we shall now proceed to give, in the author's own words, the rules of which we have spoken. That author is Robert Morris, and the work quoted is *Lectures on Architecture, consisting of Rules founded on Harmonick and Arithmetical Proportions in Building.* London, 8vo. 1734. "There are rules, likewise, for proportioning of light according to the magnitude of the room by which any room may be illuminated, more or less, according to the uses of them, and at the same time preserve an external regularity; which, as it is on an uncommon basis, I shall explain to you as well as I conveniently can. Let the magnitude of the room be given, and one of those proportions I have proposed to be made use of or any other; multiply the length and breadth of the room together, and that product multiply by the height, and the square root of that sum will be the area or superficial content in feet, &c. of the light required."

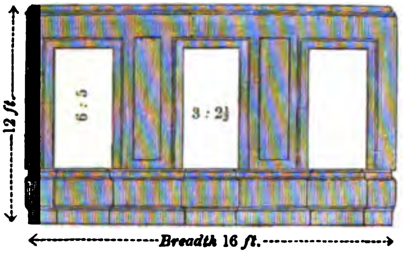

Fig. 964.

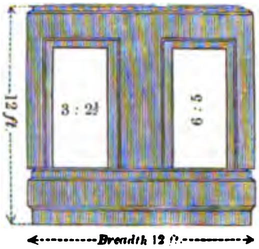

Fig. 965.

2749. "Example. Suppose a room (*fig.* 964.), whose magnitude is the arithmetical proportion of 5, 4, and 3, and is 20 feet long, 16 feet broad, and 12 feet high, the cube or product of its length, breadth, and height multiplied together is 3840, the square root of which sum is 62 feet. If the height of the story is 12 feet as before mentioned, divide that 62 feet into three windows; each window will contain 20 feet 8 inches of superficial light, and those will be found to be 3 feet 2½ inches broad, and 6 feet 5 inches high, which are windows of two diameters."

2750. "Let us now suppose another room on the same range whose height is 12 feet, as the preceding example is, and its proportion (*fig.* 965.) shall be the cube. The product of that cube is 1728, and its root is 41 feet 4 inches, or thereabouts: divide that 41 feet 4 inches in two parts for two windows, and each will be 20 feet 8 inches of superficial light, and those will be two diameters in height, and the magnitude the same as the preceding room."

2751. "For example sake, I will only suppose one more room (*fig.* 966) upon the same range, and 12 feet in height, whose proportion shall be the arithmetical of 3, 2, and 1; that is, its height being 12 feet, the breadth will be 24 and length 36, the product of those numbers multiplied together will be 10368, and its root 101 feet 8 inches, or thereabouts: divide this room into five windows, each window will have 20 feet 4 inches superficial light, and the magnitude will be near or equal to the others, and if the proportion be 6, 4, and 3, and coved, the light is the same."

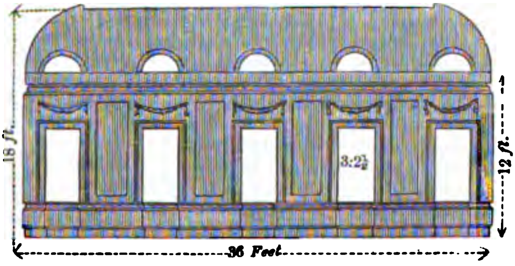

Fig. 966.

2752. "There is," says the author, rather perhaps simply, "but one objection to this rule to make it universal for all kinds of proportioned rooms on the same floor, and that is, the square root doth not always happen to be exact enough for to make them alike; but as the variation will be so small, it may be made use of; and if the area something exceeds the standard of the principal room, that room may be converted to a use which requires more than standard light, and the necessities of families sometimes require it. But, however, the rule will serve for the purpose near enough for any practice."

2753. "If you extend the rule to larger rooms, the same methods will be preserved even if the height be continued through two stories, if the upper windows be made square,

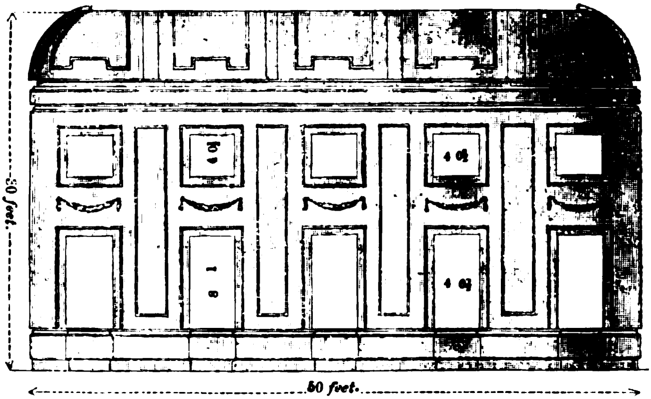

Fig. 967.

and to have two tire" (tiers) "of windows. Let us suppose the room (*fig.* 967.) with two tire of windows in height, to be 50 feet long, 40 feet wide, and 30 feet high, the arithmetical proportion of 5, 4, and 3, the product of those numbers multiplied together will be 60000, the square root of which sum is 245 superfical feet; divide that sum for the tire" (tiers) "of windows into three parts, or take one third of it, and that makes the attic or square windows 81 feet 8 inches superficial light; divide this into 5 windows, and they are 4 feet and half an inch square, and the five lower windows, consisting of 163 feet 4 inches superficial light, being what remains out of the 245 feet, the root, each of these windows is 4 feet and half an inch by 8 feet 1 inch, or two diameters, which 245 feet, the whole sum of the square root of the room, will sufficiently illuminate the same."

2754. The extreme piers should not, if possible, be less than half the width of the principal piers. This cannot always be obtained, but a much less width causes great irregularity, and that more especially when one of such end piers falls opposite a chimney breast, besides causing a great mass of shadow on the other side of the chimney, which has a tendency towards making the room dark and gloomy.

2755. Windows in the same story should be similar. There may be an occasional deviation for a great central window, but such deviation must be used with much caution. Another practice, most properly reprobated by Chambers, is that of intermitting the architrave and frieze of an order in the intervals between the columns to make room for windows and their enrichments, as on the flanks of the Mansion House in the city of London; a practice from which Sir Christopher Wren was, unfortunately, not exempt, as may be noticed in St. Paul's Cathedral.

2756. What are called Venetian windows are occasionally allowable, when so ranged and introduced as not to interfere with the composition, — a task often difficult to effect. They should not be much repeated, as in the front at Holkham, where they become actually disgusting. Though in the examples which follow there be two which are composed with semicircular-headed centres, we do not approve of the general use of examples designed on such principles, and would advise the student rather to study the composition of the Venetian window, when required, as in *fig.* 968., which we do not present as one of beauty, but rather of propriety, where the want of light to the apartment renders a Venetian window expedient. The method of making sashes, shutters, and the other accessories of windows has been described in a previous section; we therefore proceed to offer a few of the most celebrated examples of windows. It is not necessary, after the investigation relative to the voids and solids of doors, to pursue the inquiry into the relative proportions of windows as respects that part of the subject. They are, in a measure, in regard to windows, subject to the same principles, and this, by trial, will be immediately apparent to the student; and we therefore shall not stop for such investigation.

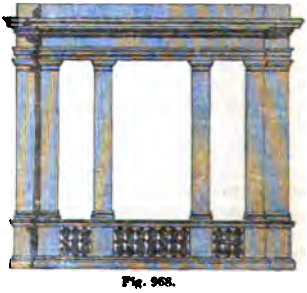

Fig. 968.

2757. *Fig.* 969. is after the lower story of windows at St. Peter's at Rome, by Michael Angelo, and is rather less than the double square in height. The architrave is one seventh of the aperture's width, being the same as that of the pilasters. The length of the consoles is one third of the width of the aperture, and the entablature one quarter of its height.

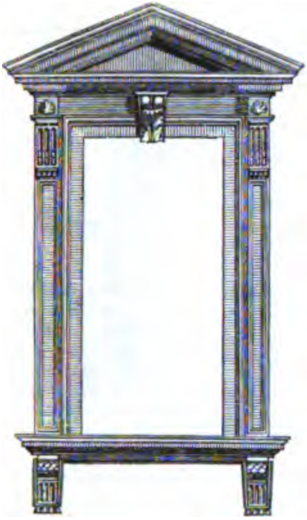
Fig. 969.

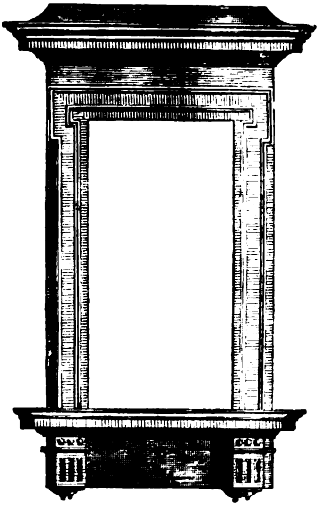
Fig. 970.

2758. *Fig.* 970. is from the Mattei palace at Rome, and is the design of Bartolomeo Ammanati. It possesses, though rather heavy, considerable beauty, and well deserves the attention of the student. Chambers, from whom we have selected many of our examples in this and others sections, says, "the parts made somewhat less would succeed better, as would also a pediment instead of the sloped covering at top:" but we entirely disagree with him, and are of opinion that what he proposes would ruin the design.

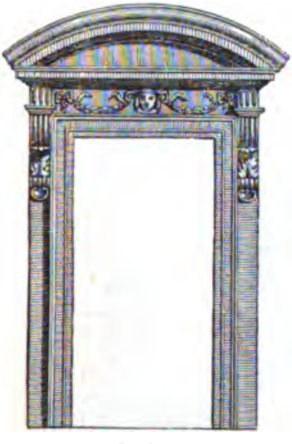
Fig. 971.

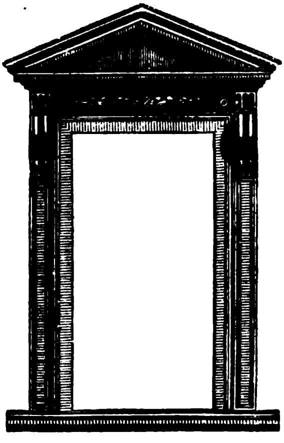
Fig. 972.

2759. *Figs.* 971. and 972. are the compositions of Bernardo Buontalenti. The apertures are a double square, or something less, the architraves a sixth or seventh of the apertures, and the pilasters may be about the same. The height of the entablature should not be more than a quarter that of the aperture, nor much less. The greatest length of the consoles should not exceed half the width of the aperture, nor should their least length be less than one third of it.

2760. *Fig.* 973. is from the old Louvre at Paris, and is by the celebrated Pierre Lescot, abbot of Clugny in the reigns of Francis I. and Henry II. Its proportions are not much dissimilar from the two last examples.

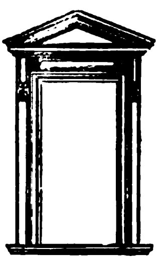

Fig. 973.

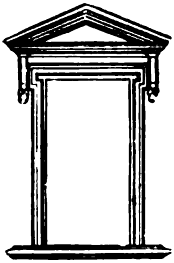

Fig. 974.

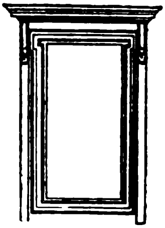

Fig. 975.

2761. *Fig.* 974. is a window constantly used by Palladio. The opening is a double square, the breadth of the architrave equal to one sixth of the aperture, and the frieze and cornice together equal to double the height of the architrave. The breadth of the consoles equal to two thirds the width of the architrave. The breaks over the consoles in the bed mouldings of the cornice are perhaps not strictly correct, but are deviations from propriety which may be tolerated. The breaks in the upper vertical parts of the architrave would perhaps be better omitted. The practice generally should be avoided, except in cases where a greater length of corniee is wanted for the purpose of filling the bare walls to which the windows are applied.

2762. *Fig.* 975. is from the Banqueting House at Whitehall, by Inigo Jones. The aperture is a double square, the entablature one fourth of its height, and the architrave somewhat more than one sixth of its width.

2763. *Fig.* 976. is by Michael Angelo, and executed at the Farnese palace at Rome. It possesses all the wildness and fancy of the master, and though abounding with faults, is redeemed by its grandeur and originality.

2764. In *fig.* 977. is given the design by Ludovico da Cigoli of a window from the ground floor of the Renuccini palace in Florence. It can scarcely be properly estimated without its connection with the façade, to the character whereof it is in every respect suitable.

2765. *Fig.* 978. is a design of Palladio, nearly resembling that executed in the Barbarano palace at Vicenza. It has been imitated by Inigo Jones, and perhaps improved on by him, in the flanks at Greenwich Hospital.

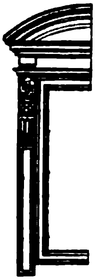

Fig. 976.

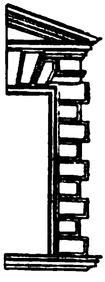

Fig. 977.

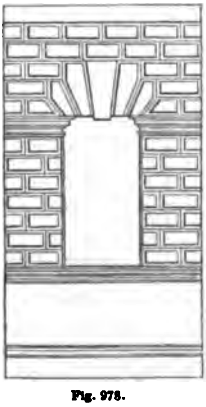

Fig. 978.

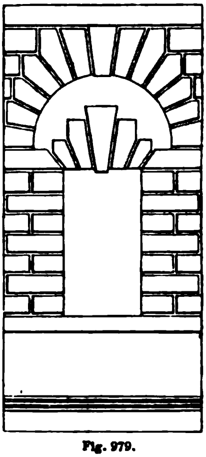

Fig. 979.

2766. *Fig.* 979. is also by Palladio, and executed by him in the Porto palace at Vicenza.

2767. *Fig.* 980. is the design of Raffaelle Sanzio, and worthy of the reputation of that great painter and architect. It is executed in the Pandolfini palace at Florence, on the principal floor. The height of the aperture is a very little more than twice its width, the architrave is one seventh the width of the aperture. The columns, which are Ionic, are 9 diameters high, and should be as much detached from the wall as possible. The distance of them from the architrave of the window is a quarter of a diameter, which is also the distance of the entablature from the top of the same architrave. The total height of the entablature is two ninths of that of the column, and the height of the pediment is one quarter of its base or somewhat less. The pedestals are one quarter of the height of the whole order.

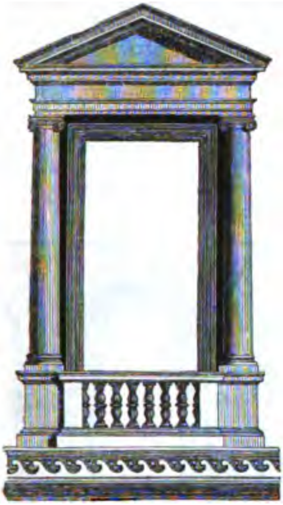
Fig. 980.

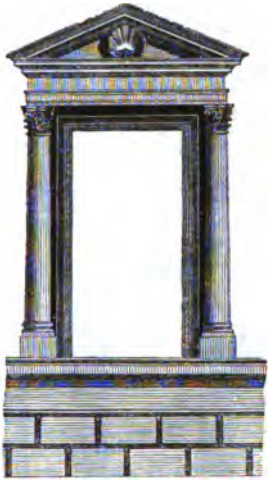
Fig. 981.

2768. *Fig.* 981. is one of the windows of the Bracciano palace at Rome, by Bernini. The aperture is more than a double square, and the architrave about one sixth the width of the aperture. The entablature is only one fifth of the height of the columns, including their sub-plinths, and the pediment is less in height than one quarter of its extent.

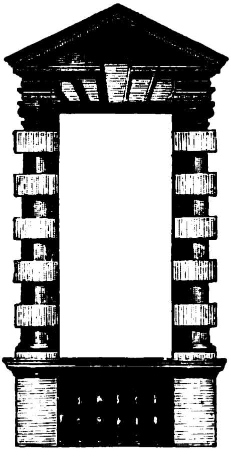
Fig. 982.

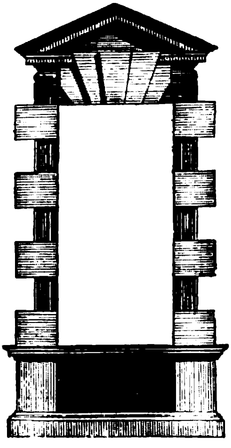
Fig. 983.

2769. *Fig.* 982. is from the principal floor of the Palazzo Thiene at Vicenza. The aperture is two and two tenths of its width in height; the columns are nine diameters high, and one quarter engaged in the wall. The under sides of the Ionic capitals are level with the top of the aperture, having angular volutes with an astragal and fillet below the volute. The bases are Tuscan, and there are on each shaft five rustic dies of an equal breadth, whose inner sides are on a line with the sides of the aperture, and their projection equal to that of the plinth of the base, that is, one fifth of a diameter of the column. The keystones incline forwards towards the top, and they are hatched, only the surface being left rough, as are likewise the dies on the columns, except at their angles, which are rubbed smooth. The entablature is Ionic, the architrave consisting of only two fasciæ, the frieze swelled, and the dentil band placed immediately on the frieze, without any intervening mouldings, a practice not very unusual with Palladio. The pedestals are rather more than one third the height of the columns. The dies and balusters stand on the platband of the basement, which was done to diminish the projection.

2770. *Fig.* 983. is a design by Inigo Jones, which has been much used in this country. It is rather higher than a double square. The width of the architrave is one fifth that of the aperture, and the rustics are a trifle less than the third of it. The entablature is two ninths of the height of the opening, and the height of the pedestal is nine twenty-fifths, or nearly the height of the aperture and pedestal taken together.

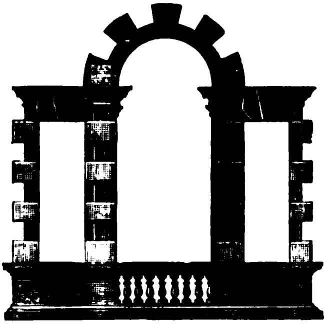

Fig. 984.

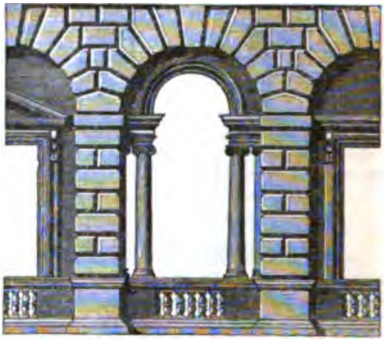

Fig. 985.

2771. *Fig.* 984. is the design of a Venetian window by Colin Campbell, the compiler of the three first volumes of the *Vitruvius Britannicus*; and

2772. *Fig.* 985. is very similar to the Venetian windows in the west façade of the Horse Guards, executed by Kent. It is perhaps as favourable an example of this species of window as can be produced.

Sect. XXI.

NICHES AND STATUES.

2773. A niche is a recess constructed in the thickness of a wall for the reception of different objects, such as statues more especially, but occasionally also for that of busts, vases, and tripods. Vitruvius makes no mention of niches, and but for an inscription published by Visconti in the *Monumenti Gabini* we should not have known that they were by the ancients called *zothecæ*, or place for the reception of a figure. Our English word niche is evidently derived from the Italian *nicchio*, a shell.

2774. In the early Greek temple the niche is not found; at a later period, as in the monument of Philopappus, we find a circular and two quadrangular-headed niches occupied in the time of Stuart by statues; and it does not seem improbable that in the Gymnasia, Agora, Stadia, &c. of the nation mentioned, the use of the niche was not uncommon. But the different forms of the ancient tomb, and the early methods of sepulture, would soon suggest to the Greeks and Romans the use of the niche, especially in such tombs as were devoted to the use of a particular family. These sepulchres, whose subdivisions were called *columbaria*, had their walls ornamented with small niches for the reception of cinerary urns, or those containing the ashes of the dead. In these, a large-sized niche occupies the principal place in the apartment, and in this was deposited the urn or sarcophagus of the head of the family.

2775. The small temples (*ædicula*) of the Romans are often found decorated with niches; and in the small building on the Lake of Albano, generally supposed to have been a Nympheum, we find each side of the interior dressed with six niches, whose height sufficiently indicates that they were provided for the reception of statues. In the temple of Diana, usually called the *maison carrée*, at Nismes, which, however, is usually considered to have been a building sacred to the Nymphs, the interior has two sides decorated with six Corinthian columns, and in the wall between each intercolumniation is a niche of the sort called tabernacles by the moderns. Each is placed on a pedestal, and is finished on the sides by pilasters alternately surmounted by segmental and triangular pediments. We do not, however, consider it necessary to enumerate the various Roman works wherein the niche finds a place, and shall therefore do no more than refer the student to the Pantheon, the temple of Peace, the arch of Janus, at Rome, and to its exuberant employment at Palmyra, Baalbek, and Spalatro. The buildings cited will furnish him with examples of all sorts and characters.

2776. The dresses of niches seem to bear an analogy to those of windows and doors in their form and decoration; the niche, indeed, may be considered as an opening in a wall, and indeed there are, in the arch of Claudius Drusus, now the Porta Maggiore, at Rome, openings used as niches, in which an object placed may be seen from either side of the wall. It therefore appears not improper to dress the niche with the ornaments which custom has sanctioned for doors and windows. The author of the article "Niche" in the *Encyclopedie Methodique*, has divided niches into three classes. The first are such as are square on the plan, and either square or circular-headed. These are the simplest, and are without dressings of any sort. Second, such as are square on their plans, and with square heads, but ornamented with dressings, or crowned with a simple platband supported by two consoles. In the third class are included all niches whose plan and heads are semicircular, either ornamented with festoons, or with dressings, or with columns and entablature. These, says the author, are to be introduced into buildings according to their several characters, from simple to highly enriched, as requisite.

2777. Some architectural authors have laid down positive rules for the proportions of niches. According to others the proportion is found in a niche twice and a half its width in height; and indeed this produces a proportion not inelegant. But in considering the classes separately, they have divided the width of the niches invariably into twelve parts. To a niche of the first class they give twenty-eight of such parts; to one of the second class, thirty; and to one of the third class, thirty-one parts. This reduction, however, of the proportions of a niche seems to us to partake of empiricism; and we would rather always trust to an educated eye than to rules which seem to have no basis on fitness and propriety. It is, however, to be recollected that all rules of art can be considered only as *mean terms*, serving more as approximations than positive laws for the guidance of the artist in the different combinations he imagines.

2778. The use of tiers of niches over each other is condemned by J. F. Blondel, unless separated by a line of entablature between them, which may seem to indicate the existence of a floor; otherwise, he observes, one figure seems to stand on the head of another. This, however, is an abuse of reasoning; not that it is to be understood that we think the practice very allowable. The recommendation of this master in respect of the relation between niches and the statues that are to occupy them is worthy of attention. He opposes, and we think with great propriety, the placing a statue without a plinth in the niche. The plinth is, indeed, necessary to the good effect of every statue; and to pretend that the imitation in marble could or ever was intended to be mistaken for the object it imitates, would be to leave behind all those matters of convention in art for which the spectator is well prepared. In architectural decoration, no less than in the abstract imitation of the objects of sculpture, no one is desirous of believing them natural and living, but only as models of imitation.

2779. The following observations are from Chambers, relative to the size of the statues used in niches. "The size of the statue depends upon the dimensions of the niche; it should neither be so large as to seem rammed into it, as at Santa Maria Maggiore, in Rome, nor so small as to seem lost in it, as in the Pantheon, where the statues do not occupy above three quarters of the height of the niche, and only one half of its width. Palladio, in arched niches, makes the chin of his statues on a level with the top of the impost (springing), so that the whole head is in the coved part. In the nave of St. Peter's, at Rome, the same proportion has been observed, and it has a very good effect. The distance between the outline of the statue and the sides of the niche should never be less than one third of a head, nor more than one half, whether the niche be square or arched; and when it is square, the distance from the top of the head to the soffite of the niche should not exceed the distance left on the sides. The statues are generally raised on a plinth, the height of which may be from one third to one half of a head; and sometimes, where the niches are very large in proportion to the architecture they accompany, as is the case when an order comprehends but one story, the statues may be raised on small pedestals, by which means they may be made lower than usual, and yet fill the niche sufficiently, it being to be feared lest statues of a proper size to fill such niches should make the columns and entablature appear trifling. The same expedient must also be made use of whenever the statues in the niches, according to their common proportions, come considerably larger than those placed at the top of the building. A trifling disparity will not be easily perceived, on account of the distance between their respective situations; but if it be great, it must have a very bad effect; and therefore this must be well attended to and remedied, either by the above-mentioned method, or by entirely omitting statues at the top of the building, leaving the balustrade either free, or placing thereon vases, trophies, and other similar ornaments." Further on in the same work, the author says that "niches, being designed as repositories for statues, groups, vases, or other works of sculpture, must be contrived to set off the things they are to contain to the best advantage; and therefore no ornaments should ever be introduced within them, as is sometimes injudiciously practised, the cove of the niche being either filled with a large scollop shell, or the whole inside with various kinds of projecting rustics, with moulded compartments, either raised or sunken, or composed of different coloured marbles, for all these serve to confuse the outline of the statue or group. It is even wrong to continue an impost within the niche, for that is of considerable disadvantage to the figures, which never appear so perfect as when backed and detached on a plain smooth surface. An excess of ornaments round the niche should likewise be avoided, and particularly masks, busts, boys, or any representation of the human figure, all which serve to divide the attention, and to divert it from the principal object."

2780. "The depth of the niche should always be sufficient to contain the whole statue, or whatever else it is to contain, it being very disagreeable to see statues, or any other weighty objects, with false bearings, and supported on consoles or other projections, as is sometimes done, and in the case of niches, the side views become exceedingly uncouth; for in these a leg, an arm, a head, in short, those parts alone which project beyond the niche, appear and look like so many fragments, stuck irregularly into the wall." We trust we shall be excused for this and many other long quotations from Chambers, on account of the strong common sense with which they abound, though not always expressed in the most elegant language that might have been selected.

2781. We conclude the section with a few examples of niches, whose general proportions are sufficiently to be derived from the figures which represent them, and which, therefore, will not require our more minute description in this place, the diagrams themselves being the more useful mode of submitting the subject to the student.

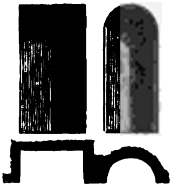
Fig. 986.

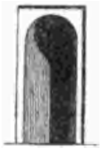
Fig. 987.

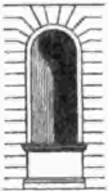
Fig. 988.

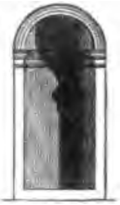
Fig. 989.

2782. *Fig.* 986. is the simple niche, square and circular in the head and in the plan; in the latter we have before, as a general rule, given the proportion of its height as twice and a half that of its width; but the former, or the square-headed one, may be a double square, yet it never should exceed in height twice and a half its width.

2783. *Fig.* 987. is a common form of using the niche where the opening of windows with which it is accompanied requires a correspondent square recess for the niches, as also in interiors where the leading lines may require such an expedient.

2784. *Fig.* 988. shows the method of introducing niches in a rusticated basement, which is often requisite. The rustics are received on a flat ground, in which the niche is formed. The reader is not to understand that any of the figures are intended as models for imitation, but merely as modes on which, in using them, he may so work as to reduce them to his own views in the design whereon he is engaged.

2785. *Fig.* 989. is from the plate of Palladio's Egyptian Hall, and exhibits the violation of Chambers's excellent maxim of not allowing the impost to be continued round the springing of the niche. If niches are merely introduced for play of light and shadow without reference to their reception of statues, the practice of this abuse may be tolerated; but certainly not in cases where statues are to be placed in them.

2786. *Fig.* 990. is the niche accompanied by entablature, pediment, architraves, consoles, and pedestals, as in the windows which have already

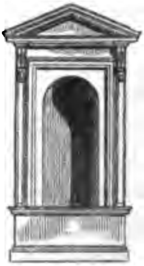
Fig. 990.

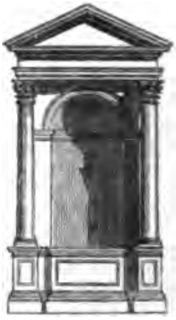
Fig. 991.

been given, and their proportions will serve as a guide in this; the only difference being, that a niche is inserted within the architrave of the opening.

2787. *Fig.* 991. is imitated from one of the niches of the Pantheon, for the details whereof the reader may refer to Desgodetz.

Sect. XXII.

CHIMNEY PIECES.

2788. It is not our intention to devote much of a space, necessarily restricted, to the consideration of designs for chimney pieces; not because we consider them unworthy of the serious attention of the student, nor because the ever-varying fashion of the day seems to create a desire for new forms, but because they come under the category of doors and windows (strange as it may seem) in respect of the relation of the void to the solid parts. We are not aware that any view of this nature has heretofore been involved in the consideration of them, but we are not the more on that account to be driven from our hypothesis. The examples of chimney pieces that have been given by Chambers, and, before him, by old Serlio, were but fashions of their respective days; and if it be possible to establish something like a canon on which they might be designed, we apprehend it would be useful to the student.

2789. A chimney piece is the ornamental decoration applied to the aperture of a chimney opening, and it seems but reasonable that in its general distribution it should be subject to those laws which regulate the ornaments of other openings. The forms and fancies into which this ornament of a room may be changed are infinite, and we therefore consider that if its appendages can be drawn into a consistent shape we shall be of service in the few remarks subjoined. In *fig.* 992. the chimney opening to be decorated is 4·0 wide and 3 feet 6 inches high; its area is therefore equal to $4:0 \times 3:6 = 14$ feet. The principle here recommended is to make the two supporting pieces equal to one half of that area, or seven feet, and the supported piece B equal to the other half. Now, as the height is 3 : 6, we shall have $\frac{7}{3 \cdot 5} = 2$ for the width of the two piers, that is, each will be one foot wide. By the addition of these to the width of the opening, the dimension becomes six feet; and as B is to contain seven feet superficial, it follows that $\frac{7}{6} = 1\frac{1}{6}$ is the height of B that it may contain 7 feet.

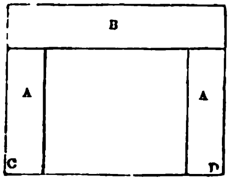

Fig. 992.

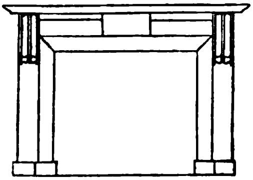

Fig. 993.

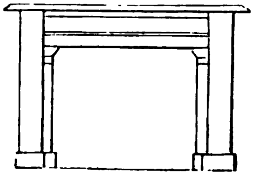

Fig. 994.

2790. In *fig.* 993. we have shown the method of developing the principle; in it the supports, load, and void bear the same relation to each other as in the preceding figure. The entablature is divided into three equal parts for the architrave, frieze, and cornice, and trusses are placed on the pilasters by the sides of the architrave. The tablet is of course not absolutely required, and the trusses may be formed of leaves instead of being plain, as here shown.

2791. *Fig.* 994. is another mode of using the proportions given in *fig.* 992., and upon it, as well as that last given, we have only to observe, they are not introduced as specimens of design, but solely with the view of illustrating a principle. The projection of chimney-pieces should not generally be greater than the whole width of the support, nor less than half.

2792. We wish we could give some rule for adjusting the size of a chimney opening to that of the room it is to warm. Morris, in his *Lectures on Architecture*, before quoted, imagined that he had found out one, and he speaks with confidence on the results which follow its use; but we confess we are not satisfied with them. We nevertheless should be wrong in omitting it, and therefore give his words for the consideration of the student. The first rule is as follows: — "To find the height of the opening of the chimney from any given magnitude of a room, add the length and height of the room together, and extract the square root of that sum, and half that root will be the height of the chimney." The second rule is as follows: — "To find the breadth of a chimney from any given magnitude of a room, add the length, breadth, and height of the room together, and extract the square root of that sum, and half that root will be the height of the chimney." The third rule he gives is, "To find the depth of a chimney from any given magnitude, including the breadth and height of the same, add the breadth and height of the chimney together, take one fourth of that sum, and it is the depth of the chimney." His fourth and last rule is, "To find the side of a square or funnel proportioned to clear the smoke from any given depth of the chimney, take three fourths of the given depth, and that sum is the side of the square of the funnel. Observe, only, that in cube rooms the height is equal to the breadth, and the foregoing rules are universal." The rules given by Chambers are extremely vague and general. He says that "in the smallest apartments the width of the aperture is never made less than from three feet to three feet six inches; in rooms from twenty to twenty-four feet square, or of equal superficial dimensions, it may be four feet wide; in those of twenty-five to thirty, from four to four and a half; and in such as exceed these dimensions, the aperture may be extended to five or five feet six inches; but should the room be extremely large, as is frequently the case of halls, galleries, and salons, and one chimney of these dimensions neither afford sufficient heat to warm the room nor sufficient space round it for the company, it will be much more convenient, and far handsomer, to have two chimney pieces of a moderate size than a single one exceedingly large, all the parts of which would appear clumsy and disproportioned to the other decorations of the room." It is well so to place the chimney as that persons on entering a room may at once see it. In this climate a cheerfulness is imparted by the sight of a fire; but it is not to be so placed as to be opposite a door, neither ought it, if possible to be avoided, to be so placed as to have a door on either side of it. There are, however, circumstances under which even the last-named category cannot be avoided, but it is always well if it can. The fact is, that the further the door can, generally speaking, be removed from a chimney, the better; and the architect must, if the plan admit it (and he ought so to distribute his parts), avoid all cross draughts of air in a room. Angular chimneys are only admissible in small rooms where space and other considerations permit no other means of introducing a chimney. We can hardly think it necessary to say, with Chambers, that "whenever two chimneys are introduced in the same room they must be regularly placed, either directly facing each other, if in different walls, or at equal distances from the centre of the wall in which they both are placed. He observes, however, with a proper caution to the student, that "the Italians frequently put their chimneys in the front walls, between the windows, for the benefit of looking out while sitting by the fire; but this must be avoided, for by so doing that side of the room becomes crowded with ornaments, and the other sides are left too bare; the front walls are much weakened by the funnels, and the chimney shafts at the top of the building, which must necessarily be carried higher than the ridges of the roofs, have, from their great length, a very disagreeable effect, and are very liable to be blown down." All these objections, however, may be easily answered, and the funnels collected, or shafts, as they then become, be, with skill, made even ornamental to a building. It is in cases like these that the power of the architect above the artisan is manifest.

2793. Where the walls of a building are sufficiently thick, their funnels rise within the thickness of the walls, but in walls of a mean thickness this cannot be accomplished, for under such circumstances the walls and chimney pieces will necessarily project into the rooms, and if the break be great, the effect is unpleasant; but this may always be obviated by making arched recesses on each side, which, in commoner rooms, may be occupied by presses or closets, thus enabling the architect to carry the cornice unbroken round the room, a point which should never be forgotten, inasmuch as by the cornice or entablature of the apartment being carried round it without a break, which gives the ceiling an unbroken and regular form, a regularity is preserved infinitely more satisfactory to the eye than the disagreeable appearance of a broken, and, we may say, disjointed cornice.

2794. Of the materials employed in the construction of chimney pieces, nothing more is requisite than to say that the costliness of the material must follow the wealth of the founder of the building. Marble, however, is the material usually employed, and the various sorts known are not unfrequently intermixed, so as to produce a pleasing effect. When the aid of the sculptor is called in, much latitude is allowed in the proportions; but on this head we hope we may, without prejudice, deliver our opinion, that the effect has never amounted to anything like what might have been expected from his extraneous aid; and the solution is easy: his object is not to produce a work in harmony with the apartment, but rather to exhibit his own powers.

2795. In the external appearance of chimney shafts, so as to group them with the building to which they belong, no architect can be put in competition with Sir John Vanbrugh. Those of Blenheim, Castle Howard, and other of his buildings, exceed all praise, and deserve the closest investigation of the student. They become in his works, as they always should do, parts of the building, inseparably connected with it, and their removal would detract from the majesty of the structure with which they are connected. On this point we are certain that the best advice that can be given to the student is a constant contemplation of the works of Vanbrugh. In these days there seems to be a return to good feeling in this respect; and we hope it will, for the credit of the English school, be followed up.

SECT. XXIII.

STAIRCASES.

2796. A staircase is an enclosure formed by walls or partitions, or both, for the reception of an ascent of stairs, with such landings as may be necessary. Of the construction of stairs we have treated in previous sections; this will be confined to general observations on them and their enclosures.

2797. Scarcely any subdivision of a building is of more importance, as respects the character of the architect and the comfort and pleasant occupancy of it by his employer, than its principal and subordinate staircases. There is, moreover, no part, perhaps, in which more room is left for architectural and picturesque display. In our own country there are some extraordinary examples of great beauty produced in staircases on comparatively small scales; whence the student may learn that without great space he may produce very imposing effects. One of these may be still seen, though in a very neglected state, as are most of the buildings attached to the collegiate church of Westminster, at one of the prebendal houses there built by our great master Jones. It is a specimen of his consummate skill as an artist, and well worth the attention of the student, if he can obtain admittance to view it; but if he cannot, we may refer him to some plates executed from drawings made by us many years since, and published in the first and best edition of *Illustrations of the Public Buildings of London* (Lond. 1828). The extreme space occupied by the staircase in question does not exceed 24 by 23 feet; and within these small dimensions he contrived a staircase fit for a palace. So highly did the late Sir John Soane think of this bijou that he had a series of drawings made to illustrate its parts, and exhibited them in his lectures at the Royal Academy.

2798. It is almost unnecessary to impress upon the student that an excess rather than a deficiency of light is requisite in a staircase, and that it should be easily accessible from all parts of the building. Those laws upon which the ease of persons ascending and descending depend will form the subject of two subsections shortly following (2804. and 2814.), to which we particularly recommend the reader's attention. They are of the utmost importance, and we record with surprise that they have not been attended to by architects generally of late years. We have crept up staircases in houses of consequence, which deserved little more than the name of ladders, and we are sorry to say that this defect is found even in the works of Chambers himself; but never in those of Jones and Wren. We shall with these remarks proceed to further observations on the subject, which has already been partially touched upon in 2176. *et seq.*

2799. We know little of the staircases of the Greeks and Romans, and it is remarkable that Vitruvius makes no mention of a staircase, as an important part of an edifice; indeed his silence seems to lead to the conclusion that the staircases of antiquity were not constructed with the luxury and magnificence to be seen in more recent buildings. The best preserved ancient staircases are those constructed in the thickness of the walls of the pronaos of temples for ascending to the roofs. Of this sort remains are found in several peripteral temples. That of the temple of Concord at Agrigentum is still entire, and consists of forty-one steps. According to Pausanias, similar staircases existed in the temple of the Olympian Jupiter at Elis. They were generally winding and spiral, like the inside of a shell, and hence are called *scale a lumaca* by the Italians, and by the French *escaliers en limaçon*. Sometimes, as in the Pantheon at Rome, instead of being circular on the plan, they are triangular; so were they in the temple of Peace, and in the baths of Dioclesian.

2800. Very few vestiges of staircases are to be seen in the ruins of Pompeii; from which it may be inferred that what there were must have been of wood, and, moreover, that few of the houses were more than one story in height. Where they exist, as in the building at the above place called the country house, and some others, they are narrow and inconvenient, with steps sometimes a foot in height. Occasionally, too, we find private staircases mentioned, as in the description of Pliny's Turculan villa, where it was placed by the side of the dining room, and appropriated to the use of the slaves who served the repast.

2801. The author of the article "Escalier" in the *Encyc. Method.* observes that the magnificence of the staircase was but tardily developed in modern architecture, and that it owed much of its luxury to the perfection to which a knowledge of stereotomy brought the science of masonry. The manners too and the customs of domestic life for a length of time rendered unnecessary more than a staircase of very ordinary description. Thus in the earliest palaces the staircases seem to have been constructed for the use of the inhabitants only, possessing in fact no more beauty than we now give to a back staircase. They are for the most part dark, narrow, and inconvenient. Even in Italy, which in the splendour of its buildings preceded and surpassed all the other nations of Europe, the staircase was, till a late period, extremely simple in the largest and grandest palaces. Such are the staircases of the Vatican, Bernini's celebrated one being comparatively of a late date. The old staircases of the Tuilleries and of the Louvre, though on a considerable scale, are, from their simplicity, construction, and situation, little in unison with the richness of the rest of these palaces. And this was the consequence of having the state apartments on the ground floor. When they were removed to a higher place, the staircase which conducted to them necessarily led to a correspondence of design in it.

2802. It will be observed that our observations in this section are confined to internal staircases. Large flights of steps, such as those at the *Trinità de' Monti* and *Araceli* at Rome, do not come within our notice, being unrestricted in their extent, and scarcely subject to the general laws of architectural composition. In these it should however be remembered that they must never rise in a continued series of steps from the bottom to the summit, but must be provided with landings for resting places, as is usually the case in the half and quarter spaces of internal stairs. An extremely fine example of an external flight of stairs may be cited in those descending from the terrace to the orangery at Versailles. For simplicity, grandeur, design, and beauty of construction, we scarcely know anything in Europe more admirable than this staircase and the orangery to which it leads.

2803. The selection of the place in which the staircase of a dwelling is to be seated, requires great judgment, and is always a difficult task in the formation of a plan. Palladio, the great master of the moderns, thus delivers the rules for observance in planning them, that they may not be an obstruction to the rest of the building. He says, " A particular place must be marked out, that no part of the building should receive any prejudice by them. There are three openings necessary to a staircase. The first is the doorway that leads to it, which the more it is in sight the better it is; and I highly approve of its being in such a place that before one comes to it the best part of the house may be seen, for although the house be small, yet by such arrangement it will appear larger: the door, however, must be obvious, and easy to be found. The second opening is that of the windows through which the stairs are lighted; they should be in the middle, and large enough to light the stairs in every part. The third opening is the landing place by which one enters into the rooms above; it ought to be fair and well ornamented, and to lead into the largest places first."

2804. " Staircases," continues our author, " will be perfect, if they are spacious, light, and easy to ascend; as if, indeed, they seemed to invite people to mount. They will be clear, if the light is bright and equally diffused; and they will be sufficiently ample, if they do not appear scanty and narrow in proportion to the size and quality of the building. Nevertheless, they ought never to be narrower than 4 feet" (4 feet 6 inches English *), " so that two persons meeting on the stairs may conveniently pass each other. They will be convenient with respect to the whole building, if the arches under them can be used for domestic purposes; and commodious for the persons going up and down, if the stairs are not too steep nor the steps too high. Therefore, they must be twice as long as broad. The steps ought not to exceed 6 inches in height; and if they be lower they must be so to long and continued stairs, for they will be so much the easier, because one needs not lift the foot so high; but they must never be lower than 4 inches." (These are Vicentine inches.) " The breadth of the steps ought not to be less than a foot, nor more than a foot and a half. The ancients used to make the steps of an odd number, that thus beginning to ascend with the right foot, they might end with the same foot, which they took to be a good omen, and a greater mark of respect so to enter into the temple. It will be sufficient to put eleven or thirteen steps at most to a flight before coming to a half-pace, thus to help weak people and of short breath, as well that they may there have the opportunity of resting as to prevent any object falling from above being there caught." We do not propose to give examples of other than the most usual forms of staircases and stairs; their variety is almost infinite, and could not even in their leading features be compassed in a work like this. The varieties, indeed, would not be usefully given, inasmuch as the forms are necessarily dependent on the varied circumstances of each plan, calling upon the architect almost on every occasion to invent *pro re natâ*.

2805. Stairs are of two sorts, straight and winding. Before proceeding with his design, the architect must always take care, whether in the straight or winding staircase, that the person ascending has what is called *headway*, which is a clear distance measured vertically from any step, quarter, half-pace, or landing, to the underside of the ceiling, step, or other part immediately over it, so as to allow the tallest person to clear it with his hat on; and this is the minimum height of headway that can be admitted. To return to the straight and winding staircase, it is to be observed, that the first may be divided into two *flights*, or be

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* The Vicentine foot is about 13·6 inches English.

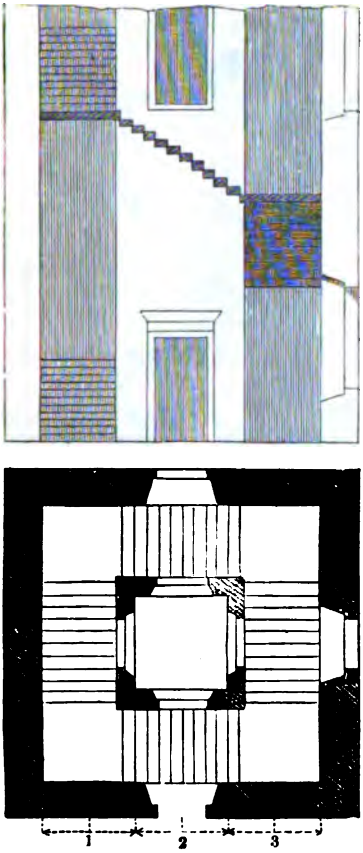

Fig. 995.

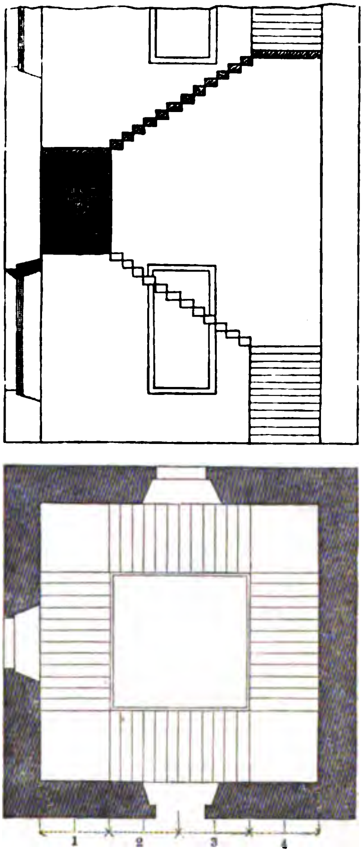

Fig. 996.

made quite square, so as to turn on the four sides round a close or open newel, as in *fig.* 995. in which the former is the case, light being obtained by windows in the walls which enclose the newel; or, as in *fig.* 996.: in which case, the newel is open, and the light may be received either from a vertical light above, or from side windows in the walls. Palladio says these two sorts of stairs were invented by Sig. Lewis Cornaro, a gentleman of much genius, who erected for himself a magnificent palace at Padua.

2806. Of winding or spiral stairs, some are circular on the plan, either open or with a solid newel; others elliptical, also with open or solid newels. Those with the open newel are preferable, because of their allowing the staircase to be lighted additionally, if requisite, by the light obtainable from above; besides which, persons passing up and down may see each other. Palladio thus directs the setting out of spiral staircases. "Those," he says, "which have a newel in the middle are made in this manner. The diameter being divided into three parts, two are given for the steps, and the third is for the newel; or, otherwise, the diameter may be divided into seven parts, three of which are for the newel and four for the steps. "Thus," he says, "was made the staircase of the column of Trajan at Rome; and if the stairs are made circular," (that is, the treads segments of circles on the plan,) "they will be handsomer and longer" (of course) "than if made straight."

2807. "But as it may happen that the space will not give room for these measures, the diameter may be reduced and divided according to the plates." The essence of these plans, omitting the step whose plan is segmental, we here subjoin.

2808. *Fig.* 997. is a plan and section of a staircase with a solid newel, in which the whole diameter is divided into thirteen parts, and of these four are given to the newel, and the remainder divided equally between the steps.

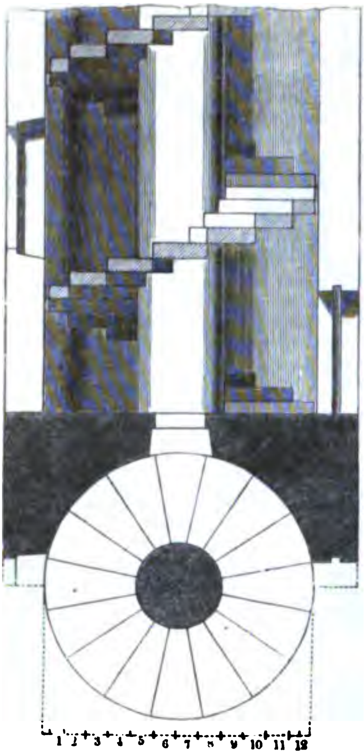

Fig. 997.

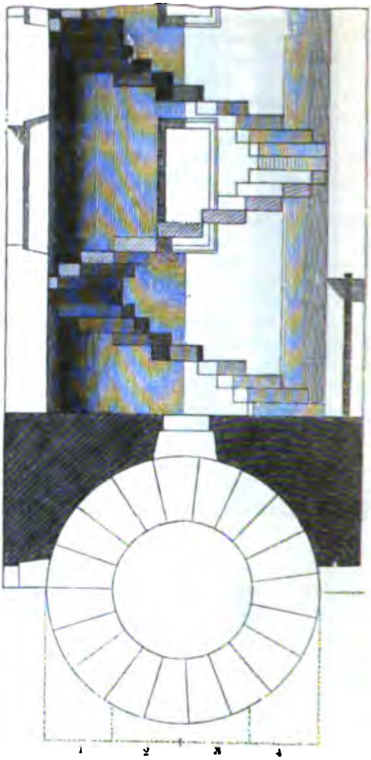

Fig. 998.

3809. *Fig.* 998. is the plan and section of a spiral staircase with an open newel, wherein the diameter is divided into four parts, two being given to the newel, and the remainder equally divided between the steps.

2810. *Fig.* 999. is the plan and section of an elliptical staircase with an open newel. The conjugate diameter is divided into four parts, whereof two are given to the conjugate diameter of the newel, and the remainder one on each side to the steps.

2811. In *fig.* 1000. the same staircase is given, but with a solid newel, and of course requiring many openings on the sides to light it.

2812. It is not the difficulty of multiplying the examples of staircases which prevents our proceeding on this head, but the space into which our work is to be condensed. Enough of example has been given, by using portions of the examples, to meet every case, the decoration being dependent on the design of the architect, and the distribution on his good sense in the application of what we have submitted to him.

2813. There is, however, one important point in the construction of a staircase to which we must now advert, and that is easiness of ascent. Blondel, in his *Cours d'Architecture*, was, we believe, the first architect who settled the proper relation between the height and width of steps, and his theory, for the truth whereof, though it bears much appearance of it, we do not pledge ourselves, is as follows.

2814. Let x = the space over which a person walks with ease upon a level plane, and z = the height which the same person could with equal ease ascend vertically. Then if h be the height of the step, and w its width, the relation between h and w must be such that when $w=x$, $h=o$, and when $h=z$, $w=o$. These conditions are fulfilled by an equation of the form $h=z\left(1-\frac{w}{2}\right)$. Blondel assumes 24 (French) inches for the value of x, and 12 for that of z. We are not sufficiently, from experiment, convinced that these are the proper values; but, following him, if those values be substituted in the equation $h=\frac{1}{2}(24-w)$, and $w=24-2h$: if the height of a step be 5 inches, its width should be $24-10=14$ inches; and it must be confessed that experience seems to confirm the theory, for it must be observed, and every person who has built a staircase will know the fact, that the merely

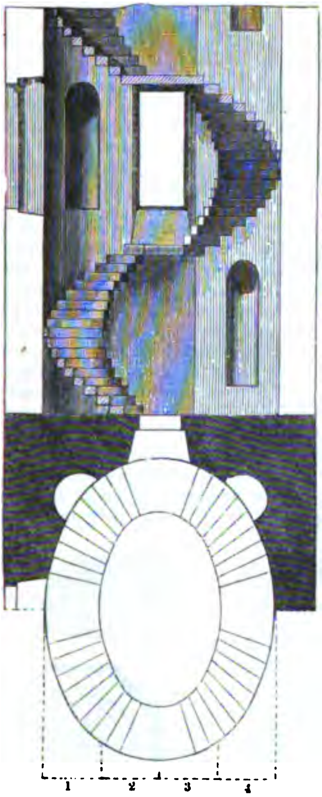

Fig. 999.

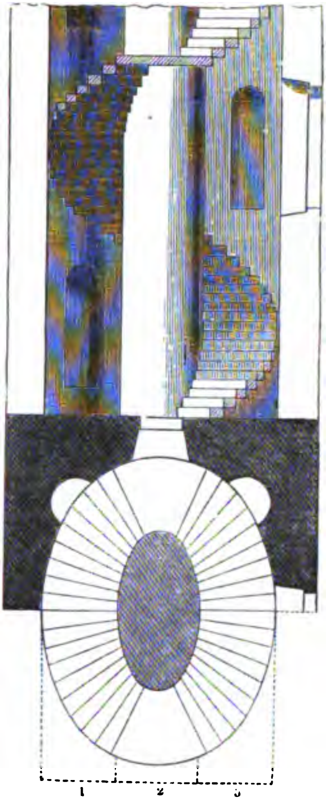

Fig. 1000.

reducing the height of the risers without giving a correspondent width of tread to the step is inconvenient and unpleasant.

SECT. XXIV.

CEILINGS.

2815. Economy has worked so great a change in our dwellings, that their ceilings are, of late years, little more than miserable naked surfaces of plaster. This section, therefore, will possess little interest in the eye of speculating builders of the wretched houses erected about the suburbs of the metropolis, and let to unsuspecting tenants at rents usually about three times their actual value. To the student it is more important, inasmuch as a well-designed ceiling is one of the most pleasing features of a room.

2816. There is, perhaps, no type in architecture more strictly useful in the internal distribution of apartments than that derived from timber-framing; and if the reader has understood our section on floors, he will immediately see that the natural compartments which are formed in the carpentry of a floor are such as suggest panels and ornaments of great variety. Even a single-framed floor with its strutting or wind-pieces between the joists, gives us the hint for a ceiling of coffers capable of producing the happiest effect in the most insignificant room. If the type of timber-framing be applied to the dome or hemispherical ceiling, the interties between the main ribs, diminishing as they approach the summit, form the skeletons of the coffers that impart beauty to the Pantheon of Agrippa. We allude thus to the type to inculcate the principle on which ornamented ceilings are designed, being satisfied that a reference to such type will insure propriety, and bring us back to that fitness which, in the early part of this Book, we have considered one of the main ingredients of beauty. If the panels of a ceiling be formed with reference to this principle, namely, how they might or could be securely framed in the timbering, the design will be fit for the purpose, and its effect will satisfy the spectator, however unable to account for the pleasure he receives. Whether the architrave be with plain square panels between it and the wall, as in the temples of the Egyptians, or as at a later period decorated with coffers, for instance in the Greek and Roman temple, the principle seems to be the same, and verifies the theory. The writer of the article "Plafond" in the *Encyc. Meth.* has not entered into the subject at much length, nor with the ability displayed in many other parts of that work; but he especially directs that where a ceiling is to be decorated on the plane surface with painting, the compartments should have reference to the construction. With these preliminary observations, we shall now proceed to the different forms in use. Ceilings are either flat, coved, that is, rising from the walls with a curve, or vaulted. They are sometimes, however, of contours in which one, more, or all of these forms find employment. When a coved ceiling is used, the height of the cove is rarely less than one fifth, and not more than one third the height of the room. This will be mainly dependent on the real height of the room, for if that be low in proportion to its width, the cove must be kept down; when otherwise, it is advantageous to throw height into the cove, which will make the excess of the height less apparent. If, however, the architect is unrestricted, and the proportions of the room are under his control, the height of the cove should be one quarter of the whole height. In the ceilings of rooms whose figure is that of a parallelogram, the centre part is usually formed into a large flat panel, which is commonly decorated with a flower in the middle. When the cove is used, the division into panels of the ceiling will not bear to be so numerous nor so heavy as when the ceiling appears to rest on the walls at once, but the same sorts of figures may be employed as we shall presently give for other ceilings. If the apartment is to be highly finished, the cove itself may be

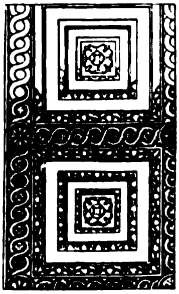
Fig. 1001.

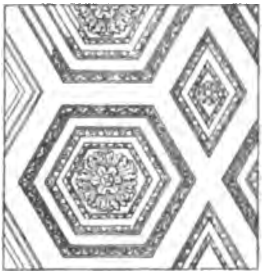
Fig. 1002.

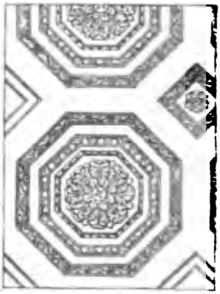
Fig. 1003.

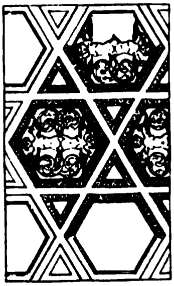
Fig. 1004.

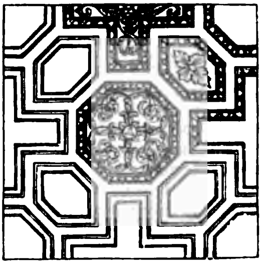
Fig. 1005.

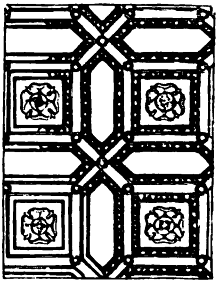
Fig. 1006.

decorated with enriched panels, as in the *figs.* 1001, 1002, 1003, 1004, 1005, 1006. In all ceilings it is desirable to raise the centre panel higher than the rest, and the main divisions representing the timbers in flat ceilings should, if possible, fall in the centre of the piers between the windows.

2817. *Fig.* 1007. shows the ceiling of a square room in two ways as given on each side of the dotted line, or it may be considered as representing the ends of a ceiling to a room whose form is that of a parallelogram. The same observation applies to *figs.* 1008. and 1009. The sofites of the beams should in all cases approach the width they would be,

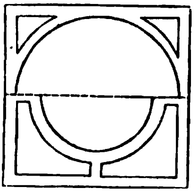

Fig. 1007.

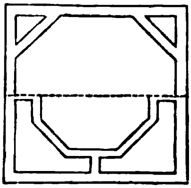

Fig. 1008.

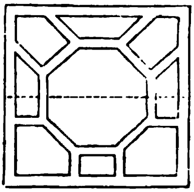

Fig. 1009.

considered as the sofites of friezes of the columns of the order to which the cornice belongs, and they may be decorated with guiloches, as in *fig.* 1010., or with frets. (See the word "Fret" in Glossary.)

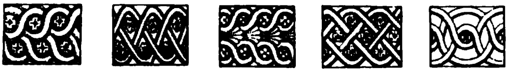

Fig. 1010.

2818. In the two following figures (1011. and 1012.) are given four examples of rooms which are parallelograms on the plan, and above each is a section of the compartments.

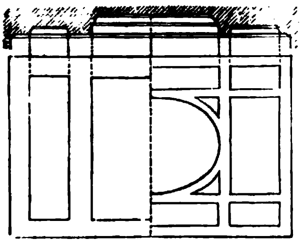

Fig. 1011

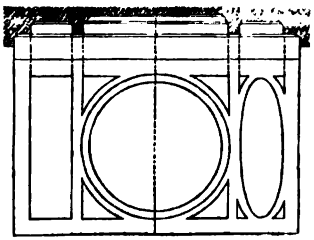

Fig. 1012.

2819. As to the proportion of the cornice, it ought in rooms to be perhaps rather less than in halls, salons, and the exterior parts of a building; and if the entablature be taken at a fifth instead of one fourth of the height, and a proportional part of that fifth be taken for the cornice, it cannot be too heavy. Perhaps where columns are introduced it will be better to keep to the usual proportions. Chambers, if followed, would make the proportions still lighter than we have set them down. He says that if the rooms are adorned with an entire order, the entablature should not be more than a sixth of the height nor be less than a seventh in flat-ceiled rooms, and one sixth or one seventh in such as are coved; and that when there are neither columns nor pilasters in the decoration, but an entablature alone, its height should not be above one seventh or eighth of those heights. He further says that in rooms finished with a simple cornice it should not exceed one fifteenth nor be less than one twentieth, and that if the whole entablature be used its height should not be more than one eighth of the upright of the room. In the ceilings of staircases the cornices must be set out on the same principles; indeed in these, and in halls and other large rooms, the whole of the entablature is generally used. In vaulted ceilings and domes the panels are usually decorated with panels similar to those in *figs.* 1001, 1002, 1003, 1004, 1005, 1006., but in their application to domes they of course diminish as they rise towards the eye of the dome. (See 2837.)

Sect. XXV.

PROPORTIONS OF ROOMS.

2820. The use to which rooms are appropriated, and their actual dimensions, are the principal points for consideration in adjusting the proportions of apartments. Abstractedly considered, all figures, from a square to the sesquialteral proportion, may be used for the plan. Many great masters have carried the proportion to a double square on the plan; but except the room be subdivided by a break the height is not easily proportioned to it. This objection does not however apply to long galleries which are not restricted in length, on which Chambers remarks, "that in this case the extraordinary length renders it impossible for the eye to take in the whole extent at once, and therefore the comparison between the height and length can never be made."

2821. The figure of a room, too, necessarily regulates its height. If a room, for example, be coved, it should be higher than one whose ceiling is entirely flat. When the plan is square and the ceiling flat the height should not be less than four fifths of the side nor more than five sixths; but when it leaves the square and becomes parallelogramic, the height may be equal to the width. Coved rooms, however, when square, should be as high as they are broad; and when parallelograms, their height may be equal to their width, increased from one fifth to one third of the difference between the length and width.

2822. The height of galleries should be at least one and one third of their width, and at the most perhaps one and three fifths. "It is not, however," says Chambers, "always possible to observe these proportions. In dwelling-houses, the height of all the rooms on the same floor is generally the same, though their extent be different; which renders it extremely difficult in large buildings, where there are a great number of different-sized rooms, to proportion all of them well. The usual method, in buildings where beauty and magnificence are preferred to economy, is to raise the halls, salons, and galleries higher than the other rooms, by making them occupy two stories; to make the drawing-rooms or other largest rooms with flat ceilings; to cove the middle-sized ones one third, a quarter, or a fifth of their height, according as it is more or less excessive; and in the smallest apartments, where even the highest coves are not sufficient to render the proportion tolerable, it is usual to contrive mezzanines above them, which afford servants' lodging-rooms, baths, *powdering-rooms*," (now no longer wanted !) "wardrobes, and the like; so much the more convenient as they are near the state apartments, and of private access. The Earl of Leicester's house at Holkham is a masterpiece in this respect, as well as in many others: the distribution of the plan, in particular, deserves much commendation, and does great credit to the memory of Mr. Kent, it being exceedingly well contrived, both for state and convenience."

2823. In this country, the coldness of the climate, with the economy of those who build superadded, have been obstacles to developing the proper proportions of our apartments; and the consequence is, that in England we rarely see magnificence attained in them. We can point out very few rooms whose height is as great as it should be. In Italy, the rules given by Palladio and other masters, judging from their works, seem to be sevenfold in respect of lengths and breadths of rooms, namely, — 1. circular; 2. square; 3. the length equal to the diagonal of the square; 4. length equal to one third more than the square; 5. to the square and a half; 6. to the square and two thirds; or, 7. two squares full. As to the height of chambers, Palladio says they are made either arched or with a plain ceiling: if the latter, the height from the pavement or floor to the joists above ought to be equal to their breadth; and the chambers of the second story must be a sixth part less than them in height. The arched rooms, being those commonly adopted in the principal story, no less on account of their beauty than for the security afforded against fire, if square, are in height to be a third more than their breadth; but when the length exceeds the breadth, the height proportioned to the length and breadth together may be readily found by joining the two lines of the length and breadth into one line, which being bisected, one half will give exactly the height of the arch. Thus, let the room be 12 feet long and 6 feet wide, $\frac{12+6}{2} = 9$ feet the height of the room. Another of Palladio's methods of proportioning the height to the length and breadth is, by making the length, height, and breadth in sesquialteral proportion, that is, by finding a number which has the same ratio to the breadth as the length has to it. This is found by multiplying the length and breadth together, and taking the square root of the product for the height. Thus, supposing the length 9 and the breadth 4, the height of the arch will be $\sqrt{9} \times 4 = 6$, the height required; the number 6 being contained as many times in 9 as 4 is in 6.

2824. The same author gives still another method, as follows: — Let the height be assumed as found by the first rule ($=9$), and the length and breadth, as before, 12 and 6. Multiply the length by the breadth, and divide the product by the height assumed; then $\frac{12 \times 6}{9} = 8$ for the height, which is more than the second rule gives, and less than the first.

CHAP. II.

COMBINATION OF PARTS.

SECT. I.

GENERAL PRINCIPLES OF COMPOSITION.

2825. THE end of architecture, without whose aid no other art can exist, is not merely to please the eye, but so to provide against the changes of the seasons as to be serviceable to man. Pleasure to the eye may, however, result from the useful, well combined with the beautiful modifications whereof it is susceptible. It is in combining thus that the genius of the architect is exhibited. The art of decorating a well-proportioned edifice is a very secondary and comparatively easy part of his work, though requiring, of course, the early cultivation of his taste and an intimate acquaintance with the parts, whereof this may be taught and that acquired; but the distribution and arrangement of the several portions on the plan, upon which every accessory is dependent, requires great knowledge and considerable experience. And in this is involved not only the general convenience and effect of the building, but what is of much consequence to the proprietor, the cost of the work. None but those practically conversant with the planning of a building would believe the saving that may be produced by proper distribution. In the case of many external breaks, for instance, much addition arises in the length of walls enclosing the edifice, without generally increasing the convenience of the interior, but always when the elevation comes to be adapted to the plan, with the certainty of breaking up the masses, and destroying the simplicity of the effect. This is mentioned merely as an instance of simplicity of plan always producing simplicity of section and elevation. The luxury and richness of decoration and the general appearance of a façade is the main source of the pleasure derivable from the exercise of the art, by persons unacquainted with it; and it is curious that these are the only matters with which the reviewer-critics of the day trust themselves, well knowing how quickly their ignorance would be discovered the moment they should pass the threshold, and discourse on the economy and distribution of a building. It is, indeed, singular in these days of art-reviewing, that for the last twenty years not a single paper of any *value* has appeared in any of the periodicals, in which the writer has ventured on that part of the subject. The fact is, that the number is very limited of those who can comprehend the plan of a building, or who, on walking over it, can so arrange in their minds the distribution of the several portions as to have the smallest notion whether it has been skilfully composed. The spectator, like the reviewer, looks at the façade, perhaps connects it in an angular view with one of the flanks, says it is heavy and mean, or grand and magnificent, according to his temperament and education, always excusing himself by admitting he does not understand architecture, but "he knows what pleases him." Now we doubt whether such persons in reality do know what pleases them, and we are certain they would be more suited for judges if they had "reason for the faith" that is in them.

2826. All ornament in architecture is non-essential, inasmuch as the pleasure received by the eye is not its end. To public and private utility, the welfare and comforts of individuals, which are the ends of the art, every other point must be sacrificed; and it is only when these have been accomplished that we are to think of decoration. We well remember the time, in our younger days, when the façade of the building to be designed was with us the important object of consideration. We have lived to know better; and the first time we seriously began, now many years since, to fall away from the error, arose from the anecdote told of a certain nobleman, who, having boasted of the beauty of the façade of his house, which within was exceedingly ill contrived, to Horace Walpole, was told that he thought the peer would do well to take the house opposite, that he might be thus always able to look at it. Those who make the internal parts of an edifice subservient to the project of a façade, and adjust their plan and section to the elevation, must be considered as making the end of less importance than the ornament of the building. Those who work in this mode produce little variety in their designs, which, numerous though they be, consist of but few different combinations, whilst those that result from the natural order of making the façade subservient to the internal parts which the plan and section impose, are susceptible of infinite variety and decoration.

2827. It is not, however, to be supposed that we are, in what has been said, sanctioning the student's neglect of careful composition and adjustment of the façades. Upon the adaptation of the different fronts of the building to sort with the internal convenience, the greatest care should be bestowed. It is from these his reputation is likely to flow, because they are the parts most susceptible of comprehension by the public. The architect will, upon every succeeding day's experience, find that the two objects are not incompatible; but if such a case, which is possible, arise, he had far better sacrifice the façade, considering first the comforts of those who are to inhabit the house, and then the gratification of those who are only to look at it.

2828. Durand has well observed that compositions conducted on the above principles must please. "Has not nature," says that author, "attached pleasure to the satisfaction of our wants, and are our most lively pleasures other than the satisfaction of our most pressing wants? These wants are better satisfied in the interior distribution of a building than in the exterior." Who leaves the Pantheon without more satisfaction than he expected from the view of the portico, fine though it be? Again, faulty as are both St. Peter's and St. Paul's, will any one who understands the subject aver that he has received more pleasure from their respective façades than from their noble interiors? The pleasurable sensations produced by both are entirely dependent on their interior distribution. But when we find that in the former of these buildings there is no mockery of a dome, the interior and exterior being as far dependent on each other as the circumstances of construction would permit, whilst the dome of the latter is worse than a mockery, the interior and exterior domes having nothing in common with each other, the last being no more than a timber leaded appurtenance to the fabric, Wren, with all his greatness, for great he was, shrinks into nothingness by the side of Michael Angelo, although the external form of the dome of London be more elegant than that of the Vatican. This is a strong but not a forced illustration of our opinions, the good sense whereof must be left for appreciation to our readers, who, we doubt not, on a little reflection, will concur with us.

2829. In ninety-nine cases out of a hundred the student will find that a good distribution of his plan leads him, with anything like ordinary tact, to the composition of good sections and good elevations, far better, indeed, than he could arrive at by pursuing an opposite course. In domestic Gothic architecture, this is notorious, for in that a regular distribution of the openings would often produce the tamest and least picturesque effect. The Gothic architects placed windows internally where only they would be serviceable, letting them take their chance in the exterior. It is not to be understood, because such would be rather *outré*, that this method will exactly suit the principles of composition in Italian architecture; but it is well known to practical men that a required opening in a particular place, instead of being a blemish, may be converted on many occasions into a beauty. Indeed, it is incontrovertibly true that distribution and disposition are the first objects that should engage the architect's attention, even of him whose great aim is to strike the attention by ornament, which can never please unless its source can be traced to the most convenient and economical distribution of the leading parts. Theorists may be laughed at, but it does not move us, nor diminish our regret to see many architects without any theory than that whereon, in an inverted position, their own wild fancies are grafted. If what we have stated be true, and from the nature of things we cannot imagine a controversy can arise upon our observations, the talent of the architect is to be estimated, as Durand properly observes, according to his solution of the two following problems: —

First. For a given sum, as in private buildings, to erect the most convenient and suitable house for his employer.

Second. The requisites in a building being given, as in public buildings, to erect it at the smallest possible expense.

2830. An investigation of all the modes of accomplishing these desiderata can only be fully effected in a work of much larger extent than this; but we have, in the practical parts of our volume, so prepared the reader, that he will not generally be at a loss in respect of the construction of a building, whatever its nature or destination.

Sect. II.

DRAWINGS NECESSARY IN COMPOSITION.

2831. In the preceding parts of the work, we have described at as great a length as could be necessary the different parts that enter into the composition of a building, such as the orders, windows, doors, balustrades, and the like, which may be compared to the notes of the scale used in musical composition. These were placed in the foremost rank of our arrangement, otherwise we must have been, as it were, without words for our discourse or notes for the symphony we would produce. We have, moreover, under the section on drawing, given such general hints for what the musician might technically call scoring them, as ought to leave him in no difficulty as to what now follows; and we have arrived at the period when he cannot be supposed to want further instructions in these respects.

2832. For the thorough comprehension of a projected edifice, at least three drawings are necessary, the *plan*, the *section*, and the *elevation*. The first is an horizontal section of it, the second the vertical section, which shows the building as if it were cut in half, and that half nearest the spectator, removed from its plan, so as to permit the inner parts to become visible, and the third is the geometrical appearance of the front represented as if viewed from an infinite distance, in which no convergence of the lines would be seen.

2833. In making a design, it is always better to put the general idea together on a single sheet of paper, and consequently, in most cases, on a small scale. This, in afterwards making the drawings, is, as may be necessary, increased in size. The three parts being drawn under one another, as shown in *fig.* 1013., wherein the middle diagram is the plan, the lower one the section, and the upper one the elevation. By thus beginning on a single sheet, in which the whole is before the eye, the corresponding lines are more readily transferred from one part to another. Having drawn through the middle of the paper the vertical AA, cut at right angles by the horizontal line BB, draw the required centres or axes of the walls CC and DD, and supposing the building is to be square, with the same opening of the compasses set out the axes of the return walls EE and FF. Having determined the thickness of the walls, one half may be set out on each side the axes, as in *ee*, *ff*, *cc*, and *dd*, and then the lines showing the thicknesses of the walls may be drawn. The width of openings in the walls may be next set out, half on each side the axes BB and AA, first drawn towards *bb* and *aa*, and the lines drawn to their places. Having thus proceeded, we shall discover that not only has the plan been drawn, but at the same time a considerable portion of the section and elevation. To distinguish the voids from the solids, the latter should be coloured or hatched, and then the next step will be as follows: — Parallel to the principal axis BB, draw the ground lines GG and GG. From these lines the heights of the building, its cornice and openings, may be set up in the section and elevation; and afterwards, the height of the roof and projection of the cornice having been determined, they may be set out and drawn. In the section, as in the plan, it is usual either to colour or hatch the solid parts, as we have done in the figure.

2834. Simple as the above process may be, it contains the whole elementary part of the mechanical process necessary for making a design. It might have been conducted on a more complicated mass, but had we done so, it would not have been so well understood, and we therefore deprecate any observations on the simpleness of our process by those who have been brought to know these things by practice and experience. We do not, however, feel we should discharge our duty before closing this section, without a censure on the attempt to convert drawings of *geometrical* elevations and sections into picturesque representations, because such practice is not only injurious to the art, but is dishonest, and has a tendency to mislead the architect's employer; and we are sorry to say that it is not unfrequently done with such a view. We denounce it, and without hesitation aver that the casting of shadows on a design is only admissible for the purpose of showing the relative depths of projecting parts; and when so admitted, the medium should be confined to Indian ink or sepia, and thrown in merely in masses, the apertures being just slightly filled in with the same colour.

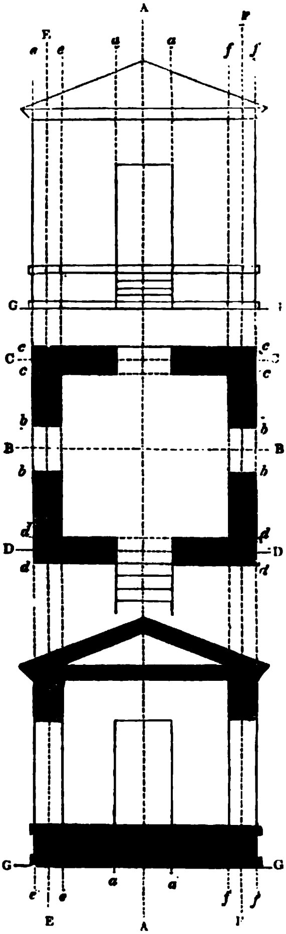

Fig. 1013.

Sect. III.

CAISSONS IN CYLINDRICAL AND HEMISPHERICAL VAULTING.

2835. Previous to further proceeding, it will be expedient to touch on the method of setting out the *caissons* or sunken panels in cylindrical vaults and domes, a process required almost in every building of importance, and imparting great beauty to the effect of the interior when properly introduced: it is, indeed, one of the elements in composing them, and must therefore be well understood before the student can succeed in developing his ideas.

2836. In setting out the ribs of cylindrical vaulting, the vertical ones are supposed as falling on supports below the springing; but if such supports fall too wide apart, the caissons themselves will be too wide, and the space must be divided into a greater number; in which case, if practicable, an odd number is to be preferred, taking care that the caissons are not too much reduced in width. This, however, is only for the purpose of ascertaining roughly how many caissons may be used in the circuit of the vault; and it is to be remembered that they must be of an odd number, because a tier of caissons should always extend along the crown of the vault. *Fig.* 1014. is an example of a cylindrical vault wherein the number of caissons is five. A is one half of its transverse section, and B a small portion of the longitudinal section. The width of the ribs between the caissons is one third of them; hence, if the number of caissons, as in the example, be five, the semi-arch must be divided into twenty-one parts, one of which parts will be the width of a rib, and three will be given to the width of a caisson. As we have just observed, a caisson is always placed in the centre, we shall therefore have the half-arch $= 1\frac{1}{2} + 1 + 3 + 3 + 1 = 10\frac{1}{2}$ and $10\frac{1}{2} \times 2 = 21$. The vertical lengths of the sides of the caissons thus found will regulate the horizontal lengths of their sides, inasmuch as they should be made square. If the caissons in the vault be seven in number, as in *fig.* 1015., the sofite or periphery must be then divided into twenty-nine parts; if their number be nine, into thirty-seven parts; and so on increasing by eight each step in the progression. The caissons may be single or double sunk, or more, according to the richness required; their centres may be moreover decorated with *fleurons*, and their margins moulded with open enrichments. Where the apartment is very highly ornamented, the ribs themselves are sunk on their face, and decorated with frets, guilloches, and the like, as mentioned for ceilings in Chap. II. Sect. XXIV. Durand, in his *Cours d'Architecture*, regulates the width of the caissons entirely by the interaxes of the columns of the building; but this practice is inconvenient, because the space may in reality be so great as to make the caissons extremely heavy, which is, in fact, the case in the examples he gives.

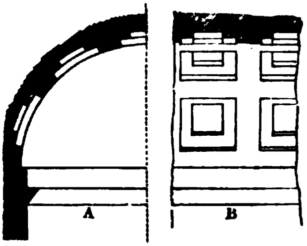

Fig. 1014.

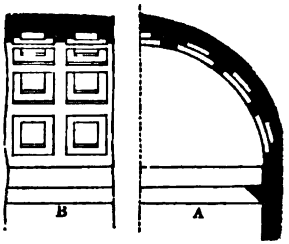

Fig. 1015.

2837. In the case of dome or hemispherical vaulting, the first point for consideration is the number of caissons in each horizontal tier of them; and the student must recollect that allowing, as before, one third of the width of a caisson as the width of a rib, the number of parts into which the horizontal periphery (whereof *e'e'* on the plan A is one quarter, and its projected representation at *ee* on the section B) is to be divided (*fig.* 1016.) must be multiples of 4, otherwise caissons will not fall centrally on the two axes of the plan. Thus,

A dome having	16 caissons in one horizontal tier must be divided into	64 parts.
—	20 ditto - - - - - -	80 ditto.
—	24 ditto - - - - - -	96 ditto.
—	28 ditto - - - - - -	112 ditto.
—	32 ditto - - - - - -	128 ditto.

and so on increasing by 16 for each term in the progression. In the figure the number of caissons is sixteen. The semi-plan is divided into thirty-two parts, three whereof are given to each caisson, and one and a half to each half-caisson on the horizontal axis of the plan. From the divisions thus obtained lines are carried up to the section *ab*, *ab*, *cd*, *cd*. As the projected representations of the great circles of a sphere are ellipses, if from *b*, *b*, *d*, *d* we construct a series of semi-ellipses whose transverse diameters are equal to the semi-diameter of the sphere, and their conjugate axes determined from the points of intersection *b*, *b*, *d*, *d*, we shall have the vertical sides of the caissons. The next part of the process is to ascertain the ratio of diminution in the heights of the tiers of caissons as they rise towards the vertex, so that they may continue square in ascending. Upon a vertical line CC′, whose length is equal to the developed length of the line of dome *ef*, or in other words, whose length is equal to one quarter of the length of a great circle of the sphere, to the right and left of C set out at *g* and *g* the half width of the caisson obtained from the plan, and make *hg*, *hg* equal to one third of the caisson for the width of the ribs on each side. Draw lines to the vertex of the developement from *hh* and *gg*. A diagonal *hi* being then drawn, the horizontal line *ik* will determine the lower edge of the next caisson upwards. Proceed in this way for the next from *l* and so on. The heights of the caissons thus obtained, being transferred to the section on the quadrant *ef*, will give the proportionate diminution thereon of the caissons as they rise. They are discontinued, and the dome is left plain, when they become so small as to lose their effect from below, and indeed they could not beyond a certain limit be executed.

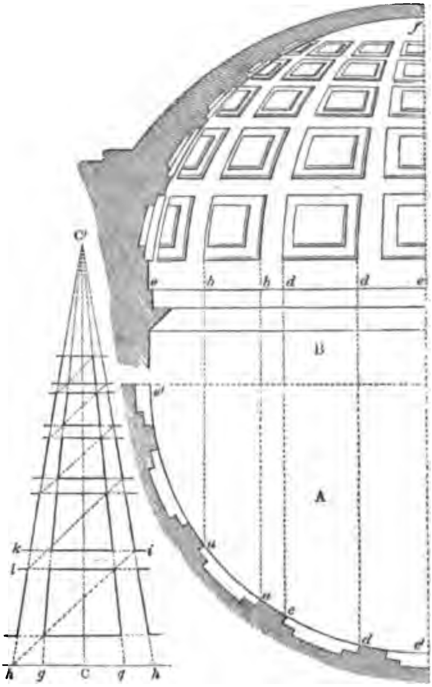

Fig. 1016.

Sect. IV.

HORIZONTAL AND VERTICAL COMBINATIONS OF BUILDINGS.

2838. The different elements of a building are ranged by the side of or above each other, and in designing an edifice both these combinations must be kept in mind, though in the study of the subject, in order to lighten the labour, they may be separately considered. The two species of disposition are horizontal, as in plans, and vertical, as in sections and elevations.

2839. As respects horizontal disposition of the elements of a fabric, beginning with columns, their distance in the same edifice should be equal, but that distance may be varied as circumstances require. In buildings of small importance, the number is reduced as much as possible, on the score of economy, by increasing the distance between them; but in public buildings they should be introduced in greater number, as contributing to the greater solidity of the edifice by affording a larger number of points of support. They ought not, however, to be at all introduced except for the formation of porticoes, galleries, and the like subdivisions. The least distance at which they can be properly placed from a wall is that which they are apart from one another. This distance, indeed, suits well enough when the columns are moderately wide apart; but when the intercolumniations are small compared with their height and the diameter of the columns, their distance from the walls in porticoes must be increased, otherwise these would be much too narrow for their height, affording shelter neither from the sun's rays nor from the rain. On this account, under such circumstances, they may be set from the walls two or three times the distance between the axes of the columns. From this arrangement will result an agreeable and suitable proportion between the parts.

2840. The ceiling of a portico may be level with the under side of the architrave, or it may be sunk the depth of the architrave, which may return in a direction towards the walls, thus forming sunk panels in the ceiling, or the sinking of the panels may be as much as the whole height of the entablature, whose mouldings should then be carried round them. When several ranks of columns occur in a portico the central part is sometimes vaulted, the two central columns of the width being omitted. The method of disposing pilasters in respect of their diminution has been treated of in a former part of this work. (2671, *et seq.*)

2841. The exterior walls which enclose the building should run as much as possible in straight continued lines from one angle to another; a straight line being the shortest that can be drawn. The internal walls, which serve for subdividing the building into its several apartments, should, as much as may be, extend from one side to the opposite one. Where they are intercepted by openings, they should be connected again above by lintels or other means.

2842. In *fig.* 1017. is shown the method of forming a plan or horizontal distribution, and combining it with the vertical distribution in the section and elevation. The thing is so simple that it can hardly want explanation. The equidistant parallel axes being drawn and cut at right angles by similarly equidistant ones, the walls, according to the required accommodations, are placed centrally upon the axes; and the columns, pilasters, &c. upon the intersections of the axes. The doors, windows, niches, and the like are then placed centrally in the interaxes, which must be bisected for that purpose. Above and below the horizontal combination the section and plan are to be drawn. These vertical combinations are infinite, and from every plan many sections and elevations may be formed. The figure exhibits a building of one story only, with a central apartment occupying the height of two stories. But on the same plan a building of two or more stories may be designed. These may have two tiers of porticoes, one above the other, or one only on the ground story, forming by its covering a terrace on the first floor; or a portico might receive on its columns the walls of the next story, and thus become recessed from the main front. So, again, the stories may be equal in height, or of different heights, as circumstances may require. The most usual practice is, above a basement to make the succeeding story higher; but above a principal floor the height of succeeding ones is diminished. The method of placing orders above orders does not require that any addition should be made to what has been said on that subject in Chap. I. Sect. II. of this Book, and by the same methods arcades over arcades may be conducted.

2843. Not the least important of the advantages resulting from the method of designing just submitted to the reader is the certain symmetry it produces, and the prevention, by the use of these interaxal lines on each floor, of the architect falling into the error of false bearings, than which a greater or more dangerous fault cannot be committed, more especially in public buildings. The subterfuge for avoiding the consequence of false bearings is now a resort to cast iron, a material beneficially enough employed in buildings of inferior rank; but in those of the first class, wherein every part should have a proper point of support, it is a practice not to be tolerated. Neither should the student ever lose sight, in respect of the ties he employs in a building, of the admirable observation of Vignola on the ties and chains proposed by Tibaldi, in his design for the baptistery at Milan: "Che le fabbriche non si hanno da sostenere colle stringhe;" — Buildings must not depend on ties for their stability. The foregoing figure is from Durand's *Precis d'Architecture*. We now submit, in *fig.* 1018., an illustration of the principles of interaxal division from the celebrated and exquisite Villa Capra, near Vicenza, by Palladio, wherein it will be seen, on comparing the result with what has actually been executed, how little the design varies from it. It will from this also be seen how entirely and inseparably connected with

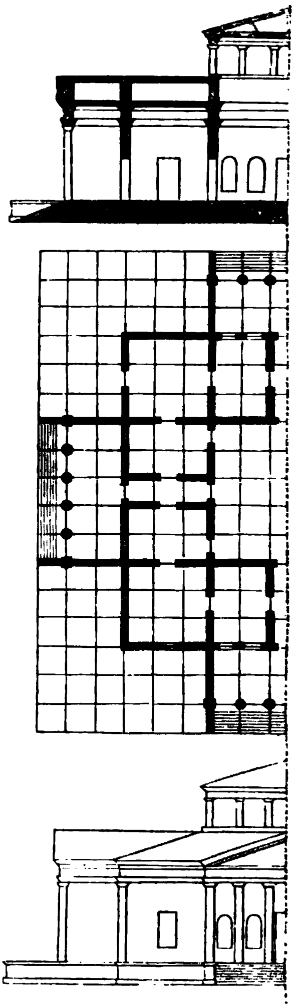

Fig. 1017.

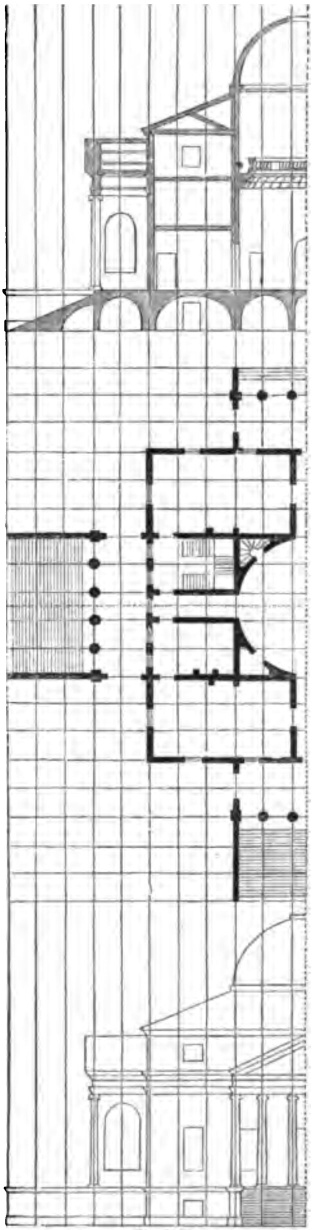

Fig. 1018.

the horizontal are the vertical combinations in the section and elevation, the voids falling over voids, and the solids over solids. Whatever the extent of the building, if it is to be regular and symmetrical in its composition, the principles are applicable, and that even in buildings where no columns are used; for, supposing them to exist, and setting out the design as though they did exist, the design will prove to be well proportioned when they are removed. The full application of the principles in question will be seen in the works of Durand, the *Précis* and *Cours d'Architecture*, which we have used freely; and where we have had the misfortune to differ from that author, we have not adopted him.

2844. The student can scarcely conceive the infinite number of combinations whereof every design is susceptible by the employment of the interaxal system here brought under his notice; neither, until he has tested it in many cases, will he believe the great mastery in design which he will acquire by its use. In the temples and other public buildings of the ancients, it requires no argument to prove that it was the vital principle of their operations, and in the courts, cavædia, &c. of their private buildings it is sufficiently obvious that it must have been extensively used. That its use in the buildings of those who are called the Gothic architects of the middle ages was universal, a glance at them will be sufficient to prove. The system of triangles which appears to have had an influence on the proportions of the early cathedrals may be traced to the same source (see the early translation of Vitruvius by Cæsar Cesarianus), and indeed, followed up to that source, would end in the principle contended for.

2845. It is impossible for us to prove that the interaxal system was that upon which the revivers of our art produced the astonishing examples many whereof are exhibited in our First Book; neither can we venture to assert that it was that upon which our great master Palladio designed the example above given, unquestionably one of his most elegant works; but, to say the least of the coincidence which has been proved between the actual design and the theory upon which it appears to have been founded, it is a very curious, and, if not true, a most extraordinary circumstance. Our belief, however, is, that not only Palladio but the masters preceding him used the system in question, and that is strengthened by the mode (not strictly, we allow, analogous) in which Scamozzi, in the tenth chapter of his third book, directs the student to adopt in buildings seated on plots of ground whose sides are irregular.

2846. To Durand, nevertheless, the public is greatly indebted for the instruction he has imparted to the student in his *Précis d'Architecture* more especially, and we regret that in our own country the art is treated by its professors too much in the manner of a trade, and that the scramble after commissions has prevented their occupation upon works similar to those which have engaged the attention of professors on the continent. The fault, however, is perhaps not, after all, so much attributable to them as to a government, whatever the party in power, till within the last five years (nay perchance even now) totally indifferent to the success of the fine arts, whose palmy days here were under the reign of the unfortunate Charles. Our feelings on this subject, and love for our art, betray us perchance too much into expressions unsuitable to the subject under consideration, and thereon we entreat, therefore, the patience of our readers, knowing "we have a good conscience."

2847. Our limits preclude the further enlargement on this part of the subject, which in detail would occupy the pages of a separate work, and which, indeed, from its nature, could not be exhausted. We trust, however, enough has been given to conduct the student on the way to a right understanding of this part of the laws of composition.

Sect. V.

SUBDIVISIONS AND APARTMENTS OF BUILDINGS AND THEIR POINTS OF SUPPORT.

2848. The subdivisions, apartments, or portions whereof a building consists are almost as many as the elements that separately compose them: they may be ranked as porticoes, porches, vestibules, staircases, halls, galleries, salons, chambers, courts, &c. &c. All these are but spaces enclosed with walls, open or covered, but mostly the latter, as the case may require. When covered, the object is accomplished by vaults, floors, terraces, or roofs. In some of them, columns are employed to relieve the bearing of the parts above, or to diminish the thrust of the vaulting. The horizontal forms of these apartments — a general name by which we shall designate them, be their application what it may — are usually squares, parallelograms, polygons, circles, semicircles, &c.; their size, of course, varying with the service whereto they are applied. Some will require only one, two, or three interaxal divisions; others, five, seven, or more. It is only these last in which columns become useful; and to such only, therefore, the system is usefully applied. The parts whereof we speak may belong to either public or private buildings: the former are generally confined to a single story, and are covered by vaults of equal or different spans; the latter have usually several stories, and are almost invariably covered with roofs or flats.

2849. When columns are introduced into any edifice to diminish the action of the vaults and increase the resistance to their thrust, the choice of the species of vault must be well considered. If, for example, the vault of a square apartment (*fig.* 1019.) of five interaxal divisions be covered with a quadrangular dome, or, in other words, a quadrantal cove, mitred at each angle, twelve columns would be required for its support. If the vault were cylindrical (*fig.* 1020.) eight columns only would be necessary; but if the form of the covering be changed to the groined arch (*fig.* 1021.), four columns only will be required. Supposing a room of similar form on the plan contained seven interaxal divisions each way, twenty columns must be employed for the coved vault, twelve columns for that whose covering was semi-cylindrical, and still but four for the groined vault. It is obvious, therefore, keeping economy in mind, that the consideration and well weighing of this matter is most important, inasmuch as under ordinary circumstances we find it possible to make four columns perform the office of twelve and even twenty. Here, again, we have proof of the value of the interaxal system, whose combinations, as we have in the previous section observed, are infinite. But the importance of the subject becomes still more interesting when we find that economy is inseparable from that arrangement whose adoption insures stability and symmetry of the parts. These are considerations whereof it is the duty of the architect who values his reputation and character never to lose sight. If honour guide him not, the commission wherewith he is intrusted had better have been handed over to the mere builder, — we mean the respectable builder, who will honestly do his best for his employer.

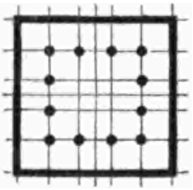
Fig. 1019.

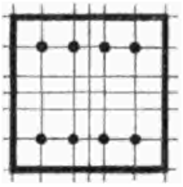
Fig. 1020.

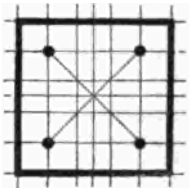
Fig. 1021.

2850. What occurs in square apartments occurs equally in those that are oblong, for the first or square is but the element of the last. If it happen that from the interaxal divisions contained in the length of an oblong or parallelogram, the subdivisions will not allow of three bays of groins, it does not follow that the arrangement must be defective, for one may be obtained in the middle bay. In subdivisions of width, allowing five interaxes, at least four columns would be saved, and in those of seven interaxes eight columns might be dispensed with. (See *fig.* 1022.)

2851. When the subdivisions on the plan, supposing it not square, take in five interaxes which in the longitudinal extent of the apartment include several bays of groins, whose number must always be odd, one column is sufficient to receive each springing of the arch, but in those of seven interaxal divisions two columns will be necessary. (See *fig.* 1023, A.)

2852. If the vaulting be on a large scale, its weight and thrust are necessarily increased, and the columns may be changed into pilasters connected with the main walls, as in *fig.* 1024., or as II in the preceding figure.

2853. The height of the apartment from the floor to the springing of the arches will be found three interaxes in apartments whose horizontal combination is of five interaxes, and four and a half for the height to springing of such as are of seven interaxal divisions on the plan. Where the combinations are different in the adjoining apartments the heights just mentioned afford the facility of lighting the larger one above the crown of the lower one, as at B in *fig.* 1023.

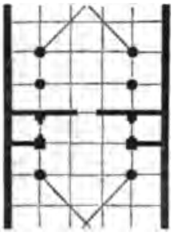

Fig. 1022.

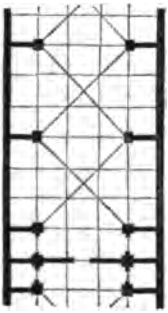

Fig. 1024.

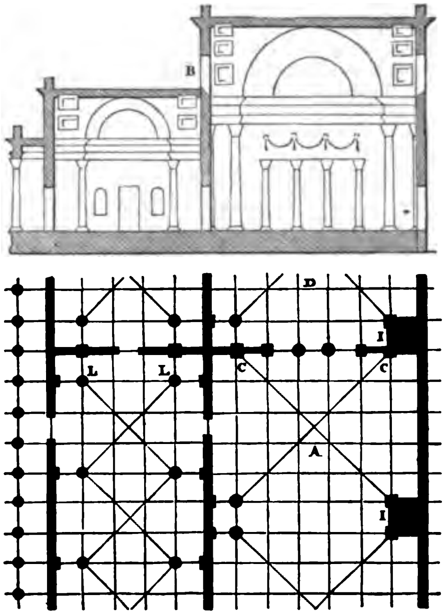

Fig. 1023.

2854. Sometimes the springing is from the walls themselves, as at C, *fig.* 1023., instead of from the columns as at L. The first of these arrangements should be permitted only when *en suite* with the apartment there is another, D, wherein the springings are from columns. When the apartment is the last of the suit, the springings must be from piers or columns, one interaxis at least from the wall. If all these matters are well understood, as also the sections upon the orders, and upon the different elementary parts of a building, a graphic combination has been established by which we shall be much aided in the composition or design of all sorts of buildings, and enabled, with little trouble, and in a much shorter period of time than by any other process, to design easily and intelligently. To do more distinguishes the man of genius from the man who can be taught only up to a certain point.

Sect. VI.

COMBINATION OF THE PARTS IN LEADING FORMS.

2855. Having shown the mode whereby the parts of a building are horizontally and vertically combined in the several apartments, which may be considered the grammar of composition, we shall now show its application in the leading forms or great divisions of the plan. Keeping in mind the advantage, upon which we have before touched, of arranging the walls of buildings as much as possible in straight lines, we should also equally endeavour to dispose the principal apartments on the same axes in each direction. Upon first thoughts the student may think that a want of variety will result from such arrangement, but upon proper reflection he will in this respect be soon undeceived. The combinations that may be made of the different principal axes are, as above stated, numberless, that is, of those axes whereon the parts may be advantageously placed so as to suit the various purposes to which the building is destined, paying also due regard to the nature of the ground whereon the fabric is to be erected.

2856. Let us, for example, take a few only of the combinations which may be formed from the simple square, as in the first sixteen diagrams of *fig.* 1025., by dividing it in both directions into two, three, and four parts. The thick lines of the diagrams may be considered as representing either walls or suits of apartments, in which latter case the open spaces between them become courts. In reference also to the vertical combinations connected with the dispositions in question, some parts of them may consist of one, other parts of two and three stories, as well for additional accommodation of the whole building to its purpose as for producing variety of outline in the elevation. If, as in some of the diagrams, we omit some of the axes used for the division, such omissions produce a new series of subdivisions almost to infinity. By this method large edifices may be most advantageously designed; it enables us to apply to the different leading axes the combinations suitable to the destination of the building. Considered however as merely an exercise for the student, the use of it is so valuable that we do not believe any other can be so beneficially employed by those masters who profess to teach the art. We have not gone into the subdivisions of the circle in detail, contenting ourselves with the two most obvious dispositions. These are susceptible of as great variety as the square, observing however that the leading axes must be concentric.

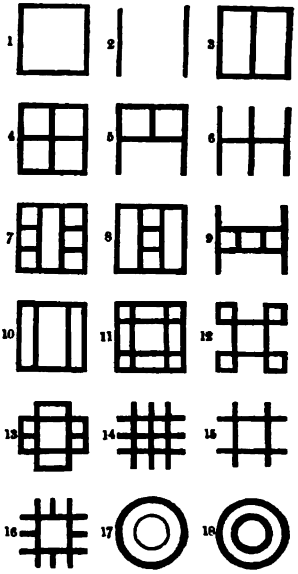

Fig. 1025.

2857. Following up the method just proposed, let us imagine a design consisting of a certain number of similar and dissimilar parts placed in certain relations to each other. Now, having fixed clearly in our mind the relative situations of the several parts and the mode by which they are connected with each other, we shall have a distinct perception of the work as a whole. We may abbreviate the expression of a design by a few marks, as in *fig.* 1026., wherein the crosses represent square apartments, and the simple lines are the expressions of parallelograms, whose relative lengths may be expressed by the lengths of the lines. The next step might be to expand these abbreviations into the form given in *fig.* 1027., on which we may indicate by curves and St. Andrew's crosses, as dotted in the diagram, the way in which the several apartments are to be covered.

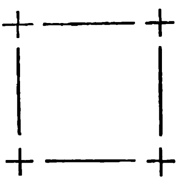

Fig. 1026.

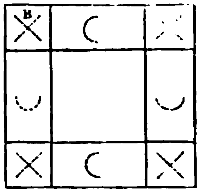

Fig. 1027.

2858. We may now proceed with the design; but first it will be well to consider one of the apartments, for which let one of the angles B be taken (see *fig.* 1027. and 1028.). Suppose it, for instance, to be five or any other number of interaxal parts square. This, then, will be the width of the apartments whose forms are that of a parallelogram; and inasmuch as in this apartment the diameter of the vault will be diminished by two interaxes, which results from the use of the four angular columns, the groined vault will be of the width of three interaxes, and the same arrangement will govern the rest of the apartments. In the centre an open court is attendant on the disposition, as indicated by the diagram. The section which is the result of the combination, subject however to other regulation in the detail, is given under the plan of the figure, and the elevation above it entirely depends upon, and is regulated by, the joint combination of the plan and section. The example is given in the most general way, and with the desire of initiating the student in the theory of his art. The building here instanced might serve some public purpose, such as a gallery for the reception of painting or sculpture, or at least give the hint for one; but our object is not to be misunderstood, — we seek only to give the tyro an insight into the principles of composition.

2859. It is not our intention to enter further on the variety which follows the method of designing, of which the foregoing are only intended as hints; but we cannot leave the subject without submitting another example for the study of the reader. Our desire is that of establishing general principles, whereof *fig.* 1029. is a more complete illustration than those that have preceded it. The abbreviated form of the horizontal disposition is shown at A, and in B it is further extended, and will be found to be very similar to that of No. 15. in *fig.* 1025. In the example the interaxal divisions are not drawn through the

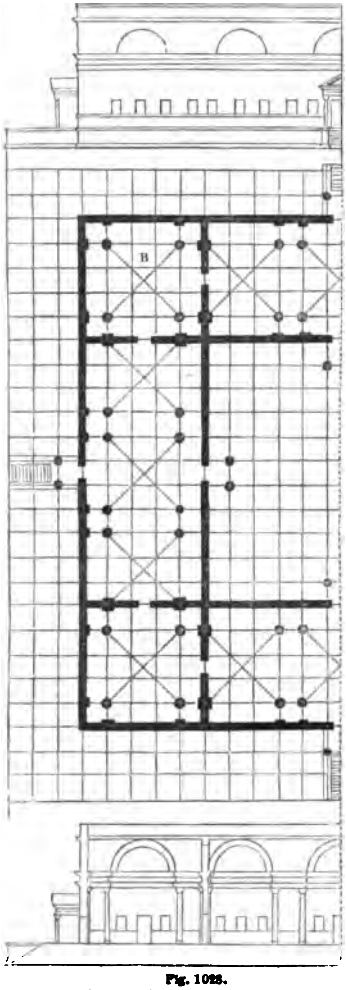

Fig. 1028.

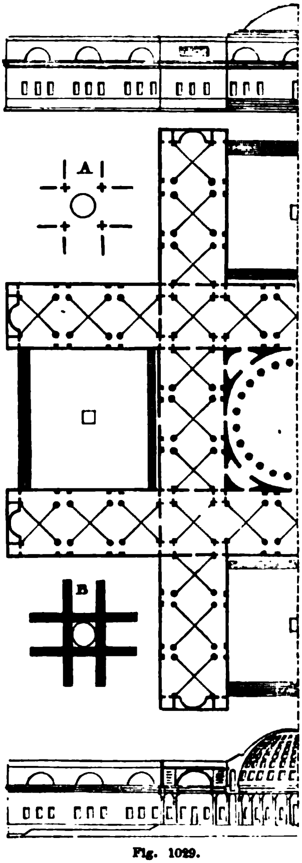

Fig. 1029.

plan, but it will be immediately seen that the space allotted to the whole width of the apartments is three in number. In the centre a circular apartment is introduced and covered with a dome, which might have been raised, in the vertical combination, another story, and thus have added more majesty to the elevation. And here we repeat, that in

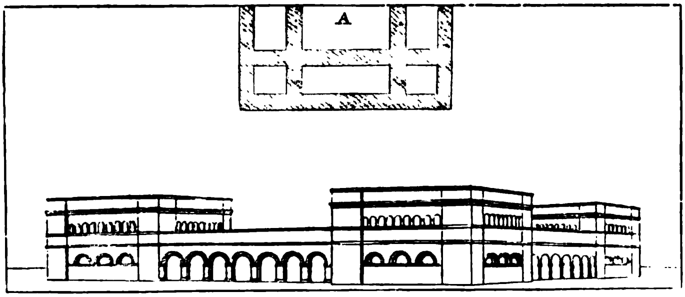

Fig. 1030.

designing buildings of more than one story, (for it cannot be too often impressed on the mind of the student,) the combination of the vertical with the horizontal distribution will suggest an infinite variety of features, which the artist may mould to his fancy, although it must be so restrained as to make it subservient to the rules upon which fitness depends.

2860. We close the chapter, not without regret, (because the subject is pleasant to us, but a treatise would not fully carry out the principles inculcated,) with an example from Durand in perspective. The general plan, A, *fig.* 1030., will be found similar to No. 11. in *fig.* 1025., and the distribution may be a good practice for the student to develope. It is an excellent example for exhibiting of what plastic nature are the buildings which the vertical combinations will admit as based on those which are horizontal.

CHAP. III.

PUBLIC BUILDINGS.

Sect. I.

GENERAL OBSERVATIONS ON PUBLIC AND PRIVATE BUILDINGS.

2861. This chapter will be devoted to such remarks on public and private buildings as may be necessary to guide the architect in their general composition. To enter into a detail of each would be impossible, neither indeed could it be useful, for there are rarely two buildings destined to the same purpose which could be erected exactly similar. More or less accommodation may be required in one than another. The site may not be suitable for the reception of similar buildings. A city will require very different buildings as to magnitude from those necessary for a town, besides many other considerations which will immediately occur to the reader.

2862. In designing public and private buildings the first object of the architect is to make himself acquainted with the uses for which the building is destined, and the consequent suitableness of the design for its purpose. He must enter into the spirit which ought to pervade the building, examining and adjusting with care those qualities which are most essential to the end proposed. Thus, though solidity be an essential in all buildings, it is more especially to be attended to in lighthouses, bridges, and the like. In hospitals, not only must the site be healthy, but the interior must be kept wholesome by ventilation and other means. In private houses almost everything should be sacrificed to the convenience and comfort of the proprietor. Security is an essential in the design and construction of prisons. Cleanliness in markets and public slaughter-houses, which we hope will, on every account, be ultimately established in suburbs, and not in the heart of every great town of the empire. Stillness and tranquillity should be provided for in places of study; cheerfulness and gaity must be the feelings with which the architect arranges places of public amusement. The next step will be to consider whether the building should consist of a single mass, and whether it will be necessary that the whole should be solid, or whether it should open interiorly on one or more courts or quadrangles; whether the different solid parts should communicate with or be separate from each other. He must also consider whether the building will abut immediately on the public way, or be placed away from it in an enclosure; whether, moreover, all the solid parts should or should not have the same number of stories.

2863. From the whole the architect must pass to the different parts or divisions, determining which of them should be principal and which subordinate; which should be near and which distant from each other, and consequently their relative places and dimensions; how they should be covered, whether by vaulting or flooring; if the former, what species of vault should be selected, and whether the bearing of the timbers or the extent of the vault will require the aid of intermediate columns. Under these considerations, the sketch being made, the interaxal divisions of each apartment set out and written thereon, the architect may add them together, and thus ascertain the whole number of interaxal divisions, so that he may see that they can be contained on the given site. This done, he should take care that none of the interaxes are too wide or too narrow compared with the scale. Should that be the case, the number of interaxal divisions must be increased or diminished accordingly, either throughout or in those parts wherein the arrangement is defective.

2864. As the number of interaxes is greater or less in the apartments, so we may now determine the order to be used below the springing of the arches. On a sketch thus conducted we shall have little more to do than to determine the profiles, ornaments, and other detail that the edifice requires. The student, by pursuing the course thus pointed out, will soon find his progress much advanced in the facility and success of designing. It is the course indicated by common sense as much in the study of the art as in the composition of designs, both of which are but an uninterrupted series of observations and reasonings.

Sect. II.

BRIDGES.

2865. Unless the design for a bridge be triumphal (a species now quite out of use), the composition can scarcely possess too much simplicity. If, indeed, in the design of a bridge we strictly adhere to the principles which regulate its convenience, stability, and economy, it will possess every beauty that can be desired. It is clear, therefore, that all applications of columns to the piers of bridges will fall under our severest censure. They can be of no service to the fabric, and are therefore unsuitable and absurd; their use moreover is a great waste of money, hence they are violations of an economical disposition in the design. We may, for illustration sake, point to the last bridge of importance erected in this country, viz. London Bridge, which is well and properly designed in comparison with Waterloo Bridge, which, though not behind the other in the requisites of strength and solidity, is inferior in the unfortunate application of columns to its piers. Had they been omitted, the deserved reputation of the engineer under whose designs it was executed would have been greatly increased, were his reputation and well-earned fame in jeopardy. The same comparison may be made between the bridge at Neuilly and that of Louis XVI., now the bridge *de la Concorde*. In the last decoration is attempted, in the former it is avoided: the last is hideous, the first agreeable.

2866. There are certain rules respecting bridges which must not be lost sight of, whereof the principal one is, that their direction must, if possible, be at right angles to the stream, and in the line too of the streets which they connect on the opposite banks of the stream. From a want of regard to these points many unfortunate blunders have been committed, which a prodigal expenditure of public money will not afterwards rectify, as we have seen in the operations consequent on the rebuilding of London Bridge. We allude to this point without the intent of blaming the parties concerned, but rather as a beacon to warn future authorities of the rock on which they may be wrecked.

2867. We had almost determined not to have introduced the section now under our pen, from the circumstance of the course of employment of the architect having latterly been so changed in favour of the engineer; but on reflection we have thought it proper, however short the notice, to say at least a little on the subject, which may be useful, from the engineer, strictly speaking, having but rarely the views in his designs of an accomplished artist; and we say this without the smallest feeling against or disrespect to the very able body of men called engineers in this country. On the equilibrium of arches and their piers, which are the chief parts of a bridge, we have in a previous part of the work already spoken, and so far explained our views on those points as to render further discussion here unnecessary. In most of the bridges of the ancients the arches were semicircular, in those of modern date they have been segmental or semi-elliptical. The last two forms are very much more suitable, because of the freer passage of the stream, especially in the case of floods.

2868. In the bridge at Pavia, over the Tesino, which is of an early period, and also a covered bridge, (a practice useless perhaps, but not uncommon in Italy and other parts of the Continent,) the arches are pointed; a form very favourable in every respect, and most especially so in rivers subject to sudden inundations, but unfavourable certainly in cases where the span of the arch is required to have a large width in proportion to its height. But the bridge just named has no common comparison with the ancient bridge. The effect resultant from its disposition is nevertheless satisfactory and magnificent, which abundantly proves that forms and proportions have less influence in producing beauty than have the qualities of propriety and simplicity.

2869. The position of a bridge should be neither in a narrow part nor in one liable to swell with tides or floods, because the contraction of the waterway increases the depth and velocity of the current, and may thus endanger the navigation as well as the bridge itself. It is the common practice, except under extraordinary circumstances, to construct bridges with an odd number of arches, for the reason, among many others, that the stream being usually strongest in the middle, egress is there better provided by the central arch. Further, too, if the bridge be not perfectly horizontal, symmetry results by the sides rising towards the centre, and the roadway may be made one continued curve. When the roadway of a bridge is horizontal, the saving of centring for the arches is considerable, because two sets of centres will be sufficient for turning all the arches. If, however, the bridge be higher in the middle than at the extremities, the arches on each side of that in the centre must diminish similarly, so that they may be respectively symmetrical on each side of the centre. From this disposition beauty necessarily results, and the centring for one of the sides equally suits the other. A bridge should be constructed with as few arches as possible, for the purpose of allowing a free passage for the water, as well as for the vessels that have to pass up and down the stream, not to mention the saving of materials and labour where the piers and centres are fewer in number. If the bridge can be constructed with a single arch, not more should be allowed. The piers must be of sufficient solidity to resist the thrust of the arch, independent of the counter thrust from the other arches; in which case the centring may be struck without the impendent danger of overturning the pier left naked. The piers should also be spread on their bases as much as possible, and should diminish gradually upwards from their foundations. The method now usually employed for laying the foundations is by means of coffer-dams, which are large enclosures formed by piling round the space occupied by the pier so as to render it water-tight, after which the water is pumped out, and the space so enclosed kept dry till the pier is built up to the average level of the water. When, however, the ground is loose, to the method mentioned recourse cannot so well be had; and then caissons must be employed, which are a species of flat-bottomed boat, wherein the pier is built up to a certain height and then sunk over the place where it is intended to remain, the bed of the river having been previously dredged out to receive it, or piles driven on which it may lodge when the sides of the chest or caisson are knocked away. The centre should be so constructed as to be unsusceptible of bending or swerving while the arches are in the course of construction, or its form will be crippled. We have diverged a little from the limits by which this section should have been circumscribed, because no other place in the work allowed us to offer the practical observations here submitted to the reader.

Sect. III.

CHURCHES.

2870. The churches whereof we propose speaking are not such as the present commissioners for building churches in this country sanction, but true good churches, such as appeared here under the reign of Queen Anne; true honest churches, one whereof is better than a host of the brick Cockney-Gothic things that are at present patronised, wherein the congregations are crammed to suffocation and not accommodated. These, therefore, we shall leave to the care of the peculiar school in which they originated, and the society to whom they more properly belong, to speak of buildings that deserve the name. Neither do we think it useful to inquire into the designs of the temples of the ancients, seeing that paganism has passed away, never to return. The largest of these temples compared to the cathedrals of the moderns was but a small affair.

2871. The early Christian worship, attended by large congregations, required for its exercise edifices whose interiors were of great extent and well lighted. Nothing was so well adapted for the purpose as the basilicæ, which, bearing the name from their resemblance to the ancient courts of justice, were raised for the purpose. Such was that of St. Paul without the walls of Rome (*figs.* 141. and 142.), the ancient St. Peter's, and many others. That of S. Giovanni Laterano was divided by four ranks of columns, which supported the walls, carrying the roofs of five aisles formed by the ranks of columns, the middle one or nave being wider and higher than the others. Each aisle being lower than that adjoining parting from the centre, admitted lights to be introduced in the several walls. The direction of the length of the nave and aisles was from east to west, and was crossed by a transverse nave called a transept from north to south. In front an ample porch or portico was provided for the assembling of the people, and for their shelter from the seasons. The distribution we have just described was, as we have mentioned in an earlier part of this work, the type of the Gothic cathedral, though it passed through two or three steps before the adaptation assumed the magnificence that would have been displayed in the church at Cologne had that structure ever been completed.

2872. The portico we consider essential to any building which deserves the name of a church, not less on account of the beauty it imparts to the edifice than for its use.

2873. The use of the modern church being the same as that of the first Christian basilicæ, it may be doubted whether for extremely large assemblies a better disposition could be chosen. The desire, however, of novelty, says Durand, induced Bramante to imitate the temple of Peace in the design for the new church of St. Peter, although that building was less a temple than a public depôt or treasury destined by Vespasian to receive the spoils from Judea. The desire, moreover, continues that author, of surpassing the ancients, by gathering into a single edifice the beauties of several, induced the same architect to crown the edifice imitated from the temple of Peace with another, imitated from the Pantheon; and in this country the same sort of thing was done by Wren in St. Paul's.

2874. It is easy to perceive that these buildings are not so well calculated for worship as the ancient basilicæ. The obstruction to seeing and hearing caused by the large piers of the modern churches is a great defect when compared with the little obstruction that the columns of the basilica present. But this is not the only blemish in the cathedral of Italian origin, as may be shown from the fact of basilicæ of the time of Constantine being still in existence; whilst the church of St. Peter, erected long posterior to that period, would in this day have been a heap of ruins, but for the enormous repairs constantly bestowed on the fabric, and the iron chains with which the dome has been girt. The cost is another serious objection to them, most especially in the construction of their domes, which are, with their tambours, buildings deficient in real solidity, from the large portion of false bearing they must involve; creating a very different sensation to that experienced in viewing the louvre of a Gothic cathedral, to which, without being insensible to the beauties of St. Peter's, St. Paul's, and other buildings of the class, we do not hesitate to give the preference.

2875. The facilities of designing a church on the principle of the basilica will be obviously those of interaxal divisions, and will not require further developement. The same method will be useful in designing the smaller parish church, with its nave and an aisle on each side, which is not only the most economical, but the best form. It was that which best pleased Sir C. Wren, whose churches are generally so planned; and we shall here give a short account of one of his best of this form, that of St. James's, Westminster, whose interior is worthy of all praise. It is an excellent example of Wren's love of harmony in proportions; the breadth being half the sum of its height and length, its height half its length, and its breadth the sesquialtera of its height: the numbers are 84, 63, and 42 feet. The church is divided transversely into three unequal parts, by a range of six columns on each side the nave, forming aisles which are each one fifth of the whole breadth, the remaining three fifths being given to the breadth of the nave. The roof is carried on these columns, and is as great a proof of the consummate skill of the architect as any portion of the fabric of St. Paul's, on account of its extreme economy and durability. It is not further necessary to describe the building; but the observations of the architect upon it are of the utmost value, emanating from such a man, to the church-builders of the present day, if it be possible to reclaim them from their pasteboard style. "I can hardly think it possible," says our architect, "to make a single room so capacious, with pews and galleries, as to hold above two thousand persons, and all to hear the service, and both to hear distinctly and see the preacher. I endeavoured to effect this in building the parish church of St. James's, Westminster, which, I presume, is the most capacious, with these qualifications, that hath yet been built; and yet at a solemn time, when the church was much crowded, I could not discern from a gallery that two thousand were present. In this church I mention, though very broad, and the middle nave arched up, yet as there are no walls of a second order, nor lanterns, nor buttresses, but the whole roof rests upon the pillars, as do also the galleries, I think it may be found beautiful and convenient, and, as such, the cheapest of any form I could invent." On the place of the pulpit in a church of this class, the same architect continues: "Concerning the placing of the pulpit, I shall observe, a moderate voice may be heard fifty feet distant before the preacher, thirty feet on each side, and twenty behind the pulpit; and not this, unless the pronunciation be distinct and equal, without losing the voice at the last word of the sentence, which is commonly emphatical, and if obscured spoils the whole sense. A Frenchman is heard further than an English preacher, because he raises his voice, and not sinks his last words. I mention this insufferable fault in the pronunciation of some of our otherwise excellent preachers, which schoolmasters might correct in the young, as a vicious pronunciation, and not as the Roman orators spoke: for the principal verb is in Latin usually the last word; and if that be lost, what becomes of the sentence?" Speaking of the dimensions of a church, the following are Wren's own words, after stating that a proposed church may be 60 feet broad, and 90 feet long, "besides a chancel at one end, and the belfry and portico at the other." "These proportions," he says, "may be varied; but to build more room than that every person may conveniently hear and see, is to create noise and confusion. A church should not be so filled with pews, but that the poor may have room enough to stand and sit in the alleys, for to them equally is the gospel preached. It were to be wished there were to be no pews, but benches; but there is *no stemming the tide of profit*, and the advantage of pew-keepers; especially, too, since by pews in the chapels of ease the minister is chiefly supported." We shall close the section by the following quotation from the same admirable artist. Quaint though the language now seem, and simple as the mind of the writer, it is of great value, and would be respected by any but commissioners for building churches. "As to the situation of the churches, I should propose they be brought as forward as possible into the larger and more open streets, not in obscure lanes, nor where coaches will be much obstructed in the passage. Nor are we, I think, too nicely to observe east or west in the position, unless it falls out properly: such fronts as shall happen to lie most open in view should be adorned with porticoes, both for beauty and convenience; which, together with handsome spires or lanterns, rising in good proportion above the neighbouring houses, (of which I have given several examples in the city, of different forms,) may be of sufficient ornament to the town, without a great expense for enriching the outward walls of the churches, in which plainness and duration ought principally, if not wholly, to be studied." Such are the common-sense remarks of a man of whom this country has to be proud, but who died neglected, the common fate of all artists who do not minister to the vanity of their employers.

2876. Churches are usually constructed on the plan of a *Greek cross*, which is that wherein the length of the transverse part, or transept, is equal to that of the nave; of a *Latin cross*, wherein the nave is longer than the transept; *in rotondo*, where the plan is a circle; *simple*, where the church has only a nave and choir; *with aisles*, when a subdivision occurs on each side of the nave; and those with aisles, as we have above seen, may have more than one of such aisles on each side of the nave.

Sect. IV.

PALACES.

2877. We regret that in this country we can offer no model of a palace for the student. Windsor Castle, with all its beauties, which however consist more in site and scenery than in the disposition of a palace, will not assist us. A palace is properly an edifice destined not only for the residence of the sovereign or prince, but for the reception also of persons who have the privilege of public or private audience. It being impossible for the whole of the parties to be present together, besides the apartments which are occupied by the sovereign and his family, there must be ample room and apartments for the attendants in waiting of every degree, and the consequent accessories. A palace should be disposed with porticoes, vestibules, galleries, halls of waiting suited to every season, wherein those to be admitted may wait with convenience and comfort till their turn of admission arrives. It is evident that, from the nature of such an edifice, much magnificence should be displayed in it. The palaces of the Escurial, Versailles, and the Tuileries are, though extremely spacious, and consequently imposing, but ill disposed and imperfect examples of a palace. Perhaps the most perfect in Europe is that of the King of Naples at Caserta, commenced in 1752, which is described by Milizia as follows:—"The plan of this palace is a vast rectangle, 731 feet long from east to west, 569 from north to south, and 106 feet in height. The interior is divided into four courts, 162 feet by 244. The depth of building that surrounds these courts, in which are the apartments, passages, &c., is 80 feet, including the thickness of the walls, which are in some instances 15 feet. The two principal façades have five stories besides that below the ground, and each contains thirty-seven windows. There are three entrances, one in the centre, and the others at equal distances between it and the extreme angles, where, as well as in the centre, the building breaks forward a little, is carried up to the height of 60 feet, and formed into pavilions by columns 42 feet high. Thus the whole height of the building is 102 feet from the foundation to the top of the pavilion, at the angles 162 feet, and in the centre 190 feet. The basement, which is rusticated, comprises the lower offices, the ground floor and its mezzanine. Above is placed an Ionic order of columns and pilasters, which contains the two ranges of state apartments; the lower windows are ornamented with pediments; in the frieze are introduced the windows of the upper mezzanine. The centre entrance leads to a superb portico, which traverses the building from north to south, and is sufficiently spacious to allow carriages to pass under from either façade to the centre of the building, where is a large octangular vestibule, which unites the arms of the cross produced by dividing the plan into four courts: two sides of the octagon are open to the portico, four to the four courts, one to the grand staircase, and the eighth is occupied by a statue of Hercules crowned by Virtue, with this inscription:—

'Virtus post fortia facta coronat.'"

2878. "The grand staircase, which is on the right, is lighted by twenty-four windows, and decorated in a beautiful style. At the first landing it is divided into two flights; the hundred steps of which it is composed are 18 feet long, and each of one piece of marble; it is lighted also from the top by a double skylight. The upper vestibule is also octangular, and surrounded by twenty-four columns of yellow marble 18 feet high. Four doors lead from thence to the apartments, the one opposite the landing to the chapel, that to the right to the apartments of the king, which comprehend the south-west angle of the building overlooking the sea and the plains of Naples and Capua. To the left are the apartments of the queen, occupying the north-west angle, the remainder of these floors being occupied by the princes. The chambers throughout are vaulted, and admirably arranged; the apartments of the king and queen are separated by a gallery 138 feet long, 42 wide, and 52 high. The palace contains a small elegant theatre, on a circular plan, divided into nine compartments, with four tiers of boxes. The chapel is rectangular in its plan, with the end terminated semicircularly, and decorated with isolated Corinthian columns on pedestals, with an entablature, in which the cornice is not omitted. The marbles and sculptures throughout are of the richest kind; the apartments generally well arranged and distributed, of magnificent dimensions, and of various forms. The whole is a rare assemblage of vastness, regularity, symmetry, richness, ease, and elegance. The multiplicity of windows may certainly be a little at variance with propriety.

" But the most wonderful part of this grand work has not as yet been described. There are ranges of aqueducts of a great height, and of sufficient length to unite the two Tifati mountains near the Furche Caudine. The waters on the mountains are collected into a canal for the purpose of supplying these aqueducts, and conducted to various lakes and fountains of every description. To the embellishments," adds Milizia, " of this royal residence are added a convenience and solidity that throw into shade all that has been done before or since." The plans, &c. of this palace may be referred to in Durand's *Parallele des Edifices.*

2879. Great as this work is, it would not have eclipsed the palace at Whitehall projected by Inigo Jones, and published in Kent's *Designs*, (see *fig.* 207., *supra*,) had the edifice, whereof the banqueting-house is not the hundredth part, been carried to completion. This palace has already been described in the First Book of this work, in turning to which the reader will find that the proposed palace consisted of six courts, and, with greater beauties of composition, would have occupied a much larger site than the palace at Caserta.

2880. We have been diffuse in the description of the last-named palace, because it contains the leading, and, indeed, governing principles, upon which the palace for a sovereign should be constructed; and from the description, the student might almost be at once led to the design of such an edifice.

2881. The designs which Bernini made at the request of Louis XIV., instigated, no doubt, by his minister Colbert, (for they were both of them lovers and patrons of the fine arts,) for uniting the Tuileries and Louvre, would, had they been executed, added another palace to which the student might have been referred for information on the subject of palaces. They may be seen in Durand's " Parallel " above mentioned, and, we think, will bear out the propriety of reference; and we fully agree with Le Grand, except in the inflated language he adopts, that " Le gouvernement qui attachera son nom a cette execution sera proclamé grand dans la posterité; il honerera la nation par les arts en reunissant ainsi les beautés eparses, incomplétes de ces deux palais, pour n'en former qu'un seul, il s'assuréra la gloire d'effacer par cette merveille celles dont, excepté les pyramides d'Egyptes l'existence n'est plus que dans l'histoire."

2882. It is almost unnecessary to observe, that the site on which a palace is to be seated must be open and free in every respect, that a large expanse of gardens should be attached to it for the use of the public as well as the sovereign, in which respect the palaces of the Tuileries and Versailles are unparalleled. All should have a royal bearing, parsimony being inadmissible in works of this nature.

Sect. V.

GOVERNMENT OFFICES.

2883. The offices of government should be designed consistently as regards their distribution and magnificence, with some respect to the power and importance of the nation for whose use they are to be constructed. Whilst on the Continent, and especially in Paris, some of the finest examples of art provide for the convenience of the different departments, the only building that can be named here in this respect are the offices at Somerset House, built by the late Sir W. Chambers. And herein so mean and indifferent to the arts has of late been every set of ministers in this country, that but for the appropriation of the eastern part of the site to a joint-stock college, it is probable the river front would never have been finished.

2884. The nature of the disposition of government buildings must of course depend on the particular department for which the building is destined, full information on which must be had in every particular before the architect can begin to imagine the building to be designed. The most ample space should be allotted to them, and no rooms for the performance of the duties attached to the department should be allowed above the first story over the ground floor. The public, indeed, ought not to have to ascend or descend even one flight of steps. The access to the different apartments should be spacious and easy;

the quadrangles, where they are necessary, should be ample, so as to afford abundance of light and air; porticoes should be provided for the shelter of the public who have to transact business, and the façades should be in a broad simple style.

2885. Without intending any affection of the fanciful style adopted by their architect, we would, in this country, point to the mode in which the offices at the Bank of England were disposed and planned by the late Sir John Soane, and the beautiful method of lighting, as highly valuable studies for the architect. The skill here exhibited by him, if not obscured by his successors, and the restless desire of change that the directors seem to exhibit, will be lasting monuments of that architect's ability, however disfigured his designs may have been by the caprice of their ornaments.

2886. The splendour of the government offices in this country seems, in every case, to be in an inverse ratio to the renown of the department. Thus, let the Admiralty be the example for consideration, and it would be difficult to decide which was worst, the interior or the exterior. On the Treasury jumble of buildings, it would be difficult to bestow a serious word. If the country be too poor to accomplish all the works at once which would be necessary for putting us in possession of buildings worthy the country, surely designs on a proper scale for rebuilding all these edifices might be made, and rigidly adhering to the designs approved after due consideration, portions might be annually executed, so as to distribute the outlay over a series of years. But we regret to say that we fear any hints under this section will be thrown away, while political parties are contending for power, and consider the comfort of the public and the promotion of the fine arts subjects of comparative insignificance. The source of the evil is in the nature of the constitution; and though, speaking as Englishmen, we do not wish to see that changed, yet we think a little more absolute power, under which there is invariably less jobbing, would be in some measure beneficial to the arts.

2887. We have hinted that there is no government building to which we should wish to refer the reader, Somerset House excepted. In Paris he will find an abundance of examples. The Admiralty there, a recent building of the most simple exterior, on which there are neither dolphins, tridents, nor anchors, as in that near Charing Cross, is a stupendous mass of building, well calculated for the narrow street in which it stands, to which it imparts unmeasured dignity. The *Garde Meuble*, as it was formerly called, in the Place de la Concorde (formerly de Louis XV.) is one of the most beautiful compositions in Europe. This is, perhaps, an example rather too florid for imitation (we do not mean in lines, but in spirit) in this country, though it is known that a well and richly-designed building costs little, if any, more than a bad, ill-digested one. The Mint of Paris is another of the French government offices worthy of the nation. But we need not multiply the instances, Paris being now almost as well known to the Englishman as London itself. It is, however, to be recollected that in France all the government buildings are of as much interest to the government in the provinces as in its metropolis, and that the great hospital at Lyons, by Soufflot, is not surpassed in Europe. In England, we know not one that approaches it.

Sect. VI.

COURTS OF LAW.

2888. A court of law in this country, speaking in more senses than one, but chiefly, here, to preserve the gravity of our work architecturally, is a building in which every one, whose business unfortunately leads him to it, sits in pain, the judges and counsel excepted. Attorneys, witnesses, jury, and audience, or public, are equally doomed to be pent up and cramped like the poor sheep at Smithfield, or a sailor in the bilboes, if that punishment be still in existence. The practice is infamous and inexcusable; it originates not with the architect, but with the government, which affords neither space nor money for the erection of courts suitable to the administration of justice, though the public are, by a pleasing assumption of the administrators of the laws, supposed to know all the decisions that take place in them, and treated by an answer to those that plead ignorance, which, but from the little of their proceedings that oozes out by that useful organ, the public press, would really be the case — "Ignorantia non excusat legem." It came out in evidence before a committee of the House of Commons on the late rebuilding of the courts at Westminster, that Sir John Soane, their architect, was told by a chief of one of the courts then proposed to be built and since executed, that *his* court, as planned, would be quite large enough to hold all *that had any business there;* rather a strange dictum for a personage whose duty, sitting on the judgment-seat, was to tell the people that their unaffected ignorance of the laws he was sworn to administer was no excuse for violating the law which might bring them before him.

2889. We have thus prefaced our short observations on this section for the purpose of impressing on the mind of the architect who may be called on to furnish designs in the provinces (for in London there is not much chance of his employment on such an occasion), that there are other persons who have equal right to as good accommodation as the judges and the bar, who are extremely well paid for the duties they perform; the parties to which we allude being the jury who are to decide upon the evidence, the witnesses from whom such evidence is derived, the attorneys whose instructions to counsel are from instant to instant necessary for the proper conduct of a case, and, though last not least, the public, who have an undoubted right to be present, not only because they are entitled to instruct themselves, as the axiom requires, that they may not be ignorant of the law, but because, in this country, the conduct of the judge himself may be open to public opinion, and his character properly transmitted to posterity, and estimated by the public.

2890. After the foregoing remarks, we apprehend it will be scarcely necessary to impress on the mind of the architect the importance of providing an ample space for the audience or public, rooms for jurymen in waiting, and full space for the latter when they are placed in what is called their *box*, so that the pain of the body may not distract the mind from the evidence of the witnesses and the charge of the judge. The artist, therefore, must be careful to supply such accommodation as shall render the office of all parties engaged a pleasing duty rather than an irksome task.

2891. To every court of law should be attached a large vestibule or salon, sufficiently large to afford a promenade for those of all classes engaged in the courts. In Westminster, bad as the courts are, this is well provided in the magnificent room called Westminster Hall, to which had the courts that open on it been in character our opening observations had been spared. It is almost needless to observe that apartments and accommodation are to be provided for the robing and occasional refreshment of the judges, the bar, and the different officers attached to the court. In courts for the trial of felons it may be necessary, if the prison has no communication with the court, to add some few cells for securing criminals. This, however, will be dependent on the circumstance mentioned, and should be provided accordingly.

2892. In these, as in other buildings where there is often congregated a great number of persons, the entrances, and at the same time outlets, should be increased in number as much as convenience and the situation will permit; and another indispensable requisite is, that the court itself should be so placed in the design that no noise created on the outside of the building may be heard in the interior, so as to interfere with the attention of those engaged on the business before them.

2893. In the provinces the observations we have made may be of some use to the student, and on this ground we have thought it our duty to offer them.

Sect. VII.

TOWN HALLS.

2894. The town hall of a city or town will necessarily vary with their extent and opulence. In towns of small extent it should stand in the market-place; indeed, in a large proportion of the towns of this country the ground floor is usually on columns, and forms the corn market of the place, the upper floor being generally sufficiently spacious for transacting its municipal business. Where the sessions or assizes, as in cities, are held in the town hall, it is necessary to provide two courts, one for the civil and the other for the criminal trials; and in this case the observations on courts of law in the preceding section equally apply to this in that respect.

2895. In cities and corporations where much municipal business occurs, the number of apartments must of course be increased to meet the exigencies of the particular case; and, if possible, a large hall should be provided for the meetings of the corporation. A certain appearance of its being the property of the public is the character to be imparted to it, and this character must be stamped on the disposition as well as the elevation. Thus, on the ground floor of the first class of town halls, courts, porticoes, or arcades, and spacious staircases should prepare for and lead to the large apartments and courts of law on the first floor. Every means should be employed in providing ample ingress and egress to the persons assembling. Fire-proof rooms, moreover, should be always provided for the records and accounts belonging to the town. The exterior of the building should not be highly decorated, but designed with simplicity, yet with majesty, as it is an index to the wealth and importance of the place for whose use it is erected.

2896. For the disposition of these buildings the student may turn with profit to the examples abroad, in which, generally, apartments are provided for every branch of the government of the city. Durand, in his *Parallèle des Edifices*, has given several examples, among which that of the city of Brussels is a beautiful instance of the application of Gothic to town architecture. It was commenced at the beginning and finished in the middle of the fifteenth century, having a tower and spire which, together, rise upwards of 360 feet from the level of the *place*. The interior of this edifice presents all the accommodations which are required for a municipality; and the principal façade, though a little disfigured by the tower not rising in the centre of it, is composed with great unity, harmony, and simplicity. Though rich, the ornaments are introduced with great order and symmetry, and the system of design pervading the front is by pyramidal masses, whose effect is exceedingly light though bold.

2897. The most celebrated of town halls in Europe is that of Amsterdam, erected during the first half of the seventeenth century by Van Campen. The design is given in Durand's *Parallèle*, and also forms the subject of a volume, in folio, published in Holland; the cost of its erection was more than thirty millions of florins, and the fabric stands, they say, on 13,659 piles, which were required from the marshy nature of the ground. The plan is nearly a square; it is 282 feet long and 255 feet wide, and its height is 116 feet. To describe the disposition of the plan would be impossible; it can only be comprehended by reference to it. The ground story in the principal façade forms the basement on which rises an order of Corinthian pilasters, containing two ranges of windows; then an entablature, and above that a repetition of similar pilasters, containing two ranges of windows. The latter are simple, having no ornament except a festoon between each range. At the angles are two pavilions, ornamented with four pilasters, and in the centre one with eight, which projects forward a little. On this a pediment rises ornamented with historical bas reliefs, and thereover, more distant, is an elegant cupola for the clock. Instead of one large principal entrance there are seven small ones, alluding, as it is said, to the seven united provinces; and it is also pleasantly said that the smallness of the provinces are typical of the smallness of the doors.

2898. We cannot, however, laud the composition of this building, which, by the way, encloses the bank and public treasury. Its merit consists mainly in the disposition of the plan, the restraint in decoration, and the good construction of the work, whilst its imposing effect results from its magnitude as a mass. The use of the Corinthian and Composite orders for such a building was almost an abuse, for their proportions vary so little from each other as almost to create confusion between the two. Again, the similarity of the subdivision in the two stories, each divided into two ranks of windows, produces a cold monotony. The windows too, without architraves, have an effect as mean as the festoons which are introduced between the windows are insipid. Neither will the excuse given for the seven small doors justify the introduction of such poverty in a building whose dimensions are so great, besides their appearance seeming to give strength to the impression that they are only entrances to the basement story. The student, on the subject of town halls, may be referred also to those of Antwerp and Maestricht and Louvain. And here we cannot refrain from alluding to the works we noticed but a little time past in the restoration, and indeed completion, of the Hotel de Ville at Paris, first commenced in 1533 on the designs of François de Cortonne, in what is now called the style of the renaissance. The additions which became necessary in consequence of the extended business of the city are executing in the same style, and will present one of the most picturesque features of the city. Such an occasion as this is a legitimate one for the employment of the style of the renaissance, and not in the trumpery stuff that appears in the country, without any solid reason for its adoption. The interior of this building, with its court or quadrangle, is not without grandeur; and the interior distribution of it, with its beautiful staircase, is a sufficient proof that what the Germans and their admirers now denominate "æsthetics" in art was well understood and practised in Italy, France, and even England, on the renaissance, whilst their country, as respects architecture, was in a state of barbarism. We regret we have not the opportunity of referring to any town hall in England which meets in all respects what we deem the requisites of such a building. We do not say that none such exist, only that it has not come to our knowledge.

Sect. VIII.

COLLEGES.

2899. A college, which is an establishment for the education of young men, generally consists in this country of one or more courts or quadrangles, round which are disposed the rooms for the students, with the chapel, library, and eating hall; apartments for the head of the establishment and for the fellows; a combination room, which is a spacious apartment, wherein the latter assemble after dinner; kitchen, buttery, and other domestic offices, laitrines, gardens, &c.

2900. In these particulars, we are speaking of English habits, for on the Continent the college is quite a different sort of thing. As, however, we consider the best instruction to the student will be concise information on those which exist, we shall shortly mention the most celebrated abroad and in England.

2901. At Rome, the college formerly that of the Jesuits, now the Roman College, is a very large edifice, simple in character, as this species of building seems to demand. Its length is 328 feet, and its height, without the attic, 87 feet. Two large gateways are placed in the middle compartment, and form the entrances to the building. In these there is nothing particularly to admire, nor in the façade generally, which is encumbered, from the nature of the edifice, with a great number of windows. The great quadrangle is, however, one of the finest in Rome, consisting of two stories of arcades, a distribution particularly applicable to buildings of this class, and which we are surprised has never found adoption in this country. In these galleries the different classes or lecture rooms are placed, under their divisions of literæ humaniores, rhetoric, and philosophy. Had the building been finished as Ammanati designed it, there would not have been in Italy a finer structure nor one more suitable to its destination. It has, by the alterations from the original plan, been much cut up; yet it is a magnificent pile of building, consisting of corridors, dormitories, gardens, refectories, and other accessories, which, with the church which forms a part of the plan, occupy a circuit of upwards of 1500 feet. The other buildings in Rome which pass under the name of colleges are not to be considered as establishments for education, being destined to the study of theology and other sciences: such are the Propaganda and the Sapienza, which last is one of the finest modern buildings of the eternal city.

2902. At Genoa is a magnificent college, which was formerly the palace of the Balbi family, by whom it was given to the Jesuits for a place of education; but, from the original destination of the building, it possesses none of the essential character which belongs to an edifice of this class.

2903. Paris, we believe, still contains nine colleges, hardly one whereof, says the author of the article "College" in the *Encyclopedie Methodique*, deserves notice. The same writer says that in England alone are found examples of what a college ought to be; and from all that we have seen on the Continent, we believe him to have come thereon to a correct conclusion.

2904. The universities of Oxford and Cambridge furnish a study for the architect in this class of building nowhere else to be found; and though the greater part of their colleges are extremely irregular in plan, they are generally convenient in disposition and highly picturesque in effect. In Oxford, the most regular in plan is Queen's College, and this is of modern construction, having been commenced as late as 1710, and in the Italian style. We are not, however, about to describe the style, which is not an example for study, but the disposition of the building. The principal front stands towards the High Street. The whole site on which the college stands is 300 feet by 220, which is divided by the chapel and hall on the right and left of the intervening building into two spacious courts. The south court, which is that nearest the street, is 140 feet long and 130 broad, having an arcade round it on the south, east, and west sides. Over that on the west side are two stories, which contain the apartments of the fellows, those of the provost, and a gallery communicating with the hall and common or combination room. The east side, which is uniform with that on the west, comprises the apartments for students of the society, and on the north side are the chapel and hall. The south side of the court or quadrangle has no dwelling in it, but is composed of a decorated wall, in whose centre is the great entrance, above whose arch an open cupola stands upon columns, and under the cupola the statue of Queen Caroline, the consort of George II. The interior court or north quadrangle is 130 feet by 90. On the north, east, and south sides are provided apartments for the members of the society, and the west is occupied by the library: the entrance to it is by a passage between the hall and chapel. The dimensions of the hall are 60 by 30 feet; those of the chapel are necessarily, as to width, the same, but it is 100 feet long. The library, which was completed earlier than the rest of the building, is 123 feet long and 30 feet broad. That the student may form an idea of the accommodation afforded on the site described, it may be taken as holding about 170 persons, including the provost and fellows, whose apartments, of course, occupy a considerable portion of the space. Hawksmoor is, as we believe, the architect; certainly, as far as we can judge, not Sir Christopher Wren, to whom some have attributed it.

2905. We have no intention to pursue the description of the colleges in either of the universities. We have selected the above as a model of disposition only, because, as we have hinted, it is in very bad taste: so bad, indeed, in that respect, as to be a model for avoidance. We shall, however, give a few more memoranda as to the parts of colleges in existence, here merely observing that a bed and sitting room, both of moderate dimensions, are as much as can be afforded to the students of the establishment.

2906. Of the colleges in Oxford, Christchurch is past question the most magnificent. Its extent, towards the street, is 400 feet. Its hall is 115 feet long, 40 feet broad, and 50 feet in height, and the entrance to it is by a very noble staircase. The chapel is the cathedral of Oxford, and is 154 feet long, and the breadth, including aisles, 54 feet. The great quadrangle is nearly 280 feet square, and this communicates with another called Peckwater quadrangle, of considerable dimensions, in which, on the south side, stands the noble library of the college, the upper room whereof is 141 feet long, 30 feet broad, and 37 feet high. At the side of and adjoining the last are the Canterbury quadrangle and Fell's Buildings, and on the other side the chaplain's quadrangle. What is called the Christchurch Meadow, attached, affords the most delightful walks for the exercise and recreation of the members, being bounded on the east by the Cherwell, on the south by the Isis, and on the west by a branch of the same river. The whole establishment is worthy of the princely founder, whose spirit seems still to reign in the conduct of those connected with it. Such a magnificent foundation cannot elsewhere be referred to.

2907. In Cambridge, the library and court of Trinity College, the former one of the finest works of Wren, and the extraordinary and beautiful chapel of King's College, are the principal features of the university. There are also some beautiful pieces of architectural composition; but as there is nothing we could select as a model for a college, which is the principal object of the section, we do not consider it necessary to detain the reader by an account of them. We may, however, mention that the chapel of King's College is 316 feet long, 84 feet broad, and 90 feet from the ground to the top of the battlements. Corpus Christi College is, perhaps, the last college in either of the universities that has been rebuilt; but in disposition, and most especially in design, it is rather an index *rerum vitandarum* than a model we should recommend to the student's attention.

Sect. IX.

PUBLIC LIBRARIES.

2908. Although a public library would seem to require a grave and simple style of treatment, it is, nevertheless, properly susceptible of much richness, if the funds admit, and it comports with the surrounding buildings to use much decoration. A public library may be considered as the treasury of public knowledge; indeed its treasures are even more important to society than the public treasures of gold and silver. It is also to be considered as a temple consecrated to study. Security against fire is the first important consideration in its construction; indeed that point ought to be deemed indispensable; and the next consideration for the accomplishment of its purpose is quietness. The first requires that no materials except stone, brick, and iron should be employed in the walls, floors, and roofs; and the last, that it should stand far removed from a public thoroughfare. Within, especially in this climate, there can scarcely be too much light, because there are always modes of excluding the excess in the brightest days of our short summers; and in the dark days of our winters no such excess can occur. Neither should the light be placed high up for the purpose of obtaining more room for the presses which are to receive the books, because even a greater space may be obtained, as in the magnificent library at Trinity College, Cambridge, by Wren, by making the presses stand against the piers at right angles with the longitudinal walls, and placing the windows between them. Moreover, the presses, when placed longitudinally against the walls, the windows being above, have the titles of the books they contain indistinct, from being too much in shadow. The library just mentioned is in every respect one of the finest works of Sir Christopher Wren. It stands on an open arcade, at the north end whereof is a vestibule, whence the ascent is by a spacious staircase to the library itself, which is 200 feet long, 40 feet wide, and 38 feet high, floored with marble, and decorated with pilasters and an entablature of the Corinthian order. Though this library is of no mean extent, we do not adduce it as an example of a large public library suited to a nation, but as a perfect model of the mode of distribution, which might be carried in principle to any extent. If the readers be very numerous, a reading room, of course, becomes necessary, which should be placed as centrally as may be to the whole mass of building, so that the labour of the attendants may be lessened, and the readers at the same time more readily served with the books wanting. The best mode of warming the apartments is by a furnace and boilers, not at all adjoining to or communicating with the building, but by carrying pipes round the apartments or in the floor, through which pipes a constant circulation of the boiling liquid is kept up, and from which a radiation of the heat takes place.

2909. The most ancient and celebrated library in existence is that of the Vatican; in the latter respect, as well on account of its size as of the number of valuable manuscripts it contains: it occupies in the suite of its apartments one of the sides of the Vatican 900 feet in length. The presses containing the books are decorated with the finest specimens of Etruscan vases. The long gallery terminates at one end by the Museum Christianum and the Stanza de' Papyri, and at the other end by the new museum, with which it communicates by a marble staircase. The ante-salon to the library is about 200 feet long and about 87 wide. In the architecture or arrangement there is nothing particularly to admire, and indeed it was not originally intended for the purpose to which it has been appropriated.

2910. We do not think it necessary to stop the reader for an account of the Medicean library at Florence, though the work of Michael Angelo. Its proportions are grand, but the details are as capricious as that great man could possibly have invented; but of the library of St. Mark at Venice we entertain the greatest admiration. We have already described this in the First Book when speaking of the Venetian school. Notwithstanding the difficulties that Sansovino had to encounter in respect of its site and connection with other buildings, which restricted the design in the façade, because of the height of the adjoining *Procurazie Vecchie*, and the width of the ground; — notwithstanding all these, and the jealousy of his enemies superadded, Palladio considered the success of it to have been so great as to have made it worthy of any age.

2911. The splendid collection of books at Paris, containing 900,000 and upwards printed volumes, called the Bibliothéque du Roi, is, speaking architecturally, though of immense extent, little more than a warehouse for holding the books: that, however, of the abbey of St. Geneviève in the same city, though containing less than a quarter of the number just mentioned of printed volumes and 30,000 MSS., is a well-conceived and well-designed building, and particularly suited to its destination. The plan is that of a large Greek cross, which affords on the plan four large halls, connected by a central circular apartment crowned with a dome.

2912. Perhaps one of the most absurd dispositions of plan for the buildings under consideration is to be seen in the Radcliffe Library at Oxford. It is circular on the plan, and hence vast loss of room is experienced; but we do not think it necessary further to enter into its demerits, merely stating here that it was unworthy of Gibbs, who in most of his works exhibited great good sense.

Sect. X.

MUSEUMS.

2913. A museum is a building destined to the reception of literary or scientific curiosities, and for that of the works of learned men and artists. The term was first applied to that part of the palace at Alexandria appropriated solely to the purpose of affording an asylum for learned men; it contained buildings and groves of considerable magnificence, and a temple wherein was a golden coffin containing the body of Alexander. Men of learning were here lodged and accommodated with large halls for literary conversations, and porticoes and shady walks, where, supplied with every necessary, they devoted themselves entirely to study. The establishment is supposed to have been founded by Ptolemy Philadelphus, who here placed his library. It was divided into colleges or companies of professors of the several sciences, and to each of such professors was allotted a suitable revenue. Museums, in the modern sense of the word, began to be established about the sixteenth century, when collections were formed by most of the learned men who studied natural history.

2914. Museums on a small scale are becoming every day more common in the principal towns of this country, and we hope the day is not distant when none will be without its collections of science, literature, and art. Where economy requires it, and the collection in each department be not too large, the whole may be properly and conveniently comprised within one building. In respect of security against fire, and quietness of the situation, the same precautions will be necessary as are indicated for libraries in the preceding section, and must always be observed.

2915. Great skill is necessary in introducing the light properly on the objects in a museum, inasmuch as the mode of throwing the light upon objects of natural history is very different from that which is required for pictures, and this, again, from what sculpture requires.

2916. Specimens illustrating natural history, sculpture, vases, and the like, should, if possible, be lighted vertically; and we have seen in subsec. 2774., where reference is made to the light introduced into the Pantheon, how very small an opening in a spherical ceiling will produce abundance of light. There are subjects, nevertheless, in all these classes, (in mineralogy for example,) for which strong side lights are essential to an advantageous exhibition of them. In such cases small recesses may be practised for the purpose. At the

Hotel de Monnaies at Paris, the presses which contain the collection of mineralogy form a circle which encloses a small lecture theatre, and thus become doubly serviceable. We mention this *en passant* that the student may be aware how room is to be gained when the area of a site is restricted. Picture galleries in a museum, as elsewhere by themselves, when containing large paintings, should be lighted from above. In this case the lights should be in square or polygonal tambours, whose sashes should be vertical or slightly inclined inwards, their forms following the form on the plan of the rooms. The noble pictures of Paul Veronese at the Louvre could not be seen with side lights. For small cabinet pictures side lights are well adapted to their display. Every one will recollect how miserably lighted for exhibiting the pictures is the long gallery of the Louvre; the same may be said, though not to so great an extent, of the collection of sculpture, whilst the models and other objects, paintings excepted, in the Vieux Louvre, are exhibited to perfection.

2917. Where the same museum is to contain several classes of objects the suites of rooms for the different departments should be accessible from some central one common to all: this may be circular or polygonal, as may best suit the arrangement and means; and, if possible from the site, the building should not consist of more than one story above the ground; on no account of more than two.

2918. For the objects it contains we question whether the British Museum is surpassed, as a whole, in Europe; and those of the Vatican, of the Uffizj at Florence, of Portici, and of Paris, are none of them of sufficient architectural importance to detain the reader by description; neither would they, if so described, be useful to the student as models. At Munich the Glyptotek for sculpture, and the Pinacotek for pictures, are in some respects well suited to the exhibition of the objects deposited in them, better, indeed, than is the museum at Berlin. These have all been much praised by persons of incompetent judgment as specimens of fine architecture; but we cannot recommend the study of them to any one who is desirous of acquiring a pure taste in the art, nor indeed any other works of the modern German school.

2919 In the composition of museums decoration must not be exuberant. It must be kept in the interior so far subordinate as not to interfere with the objects to be exhibited, which are the principal features of the place. With this caution we do not preclude the requisite degree of richness which the architecture itself requires. Using the shorthand of the previous chapter ⌖, the Greek cross, connected by a dome in the centre, for the great hall of communication, is perhaps as good a form for a museum on a small scale as could be adopted: however, this is a matter which would form an admirable exercise for the student.

Sect. XI.

OBSERVATORIES.

2920. We had great doubts upon the admission of this section, not because of its want of importance, but because we can scarcely bring ourselves to the conviction that traversing domes for equatorial instruments and chases in a roof for fixed ones can be ever united with beauty of design. The observatory at Paris, from the designs of Perrault, is a noble building, but, we believe, is universally admitted to be very ill suited to the purposes for which it was built. Hence we shall be brief in what we have to say under this section.

2921. A *regular* observatory is one where instruments *are* fixed in the meridian, whereby, with the assistance of astronomical clocks, the right ascensions and declinations of the heavenly bodies are determined, and thus motion, time, and space are converted into measures of each other. On the observations and determinations made in such establishments they are therefore, to maritime states, of vital importance, and ought to be liberally endowed by their governments. As the subject will be better understood by a plan, we subjoin, in *fig.* 1031., a plan and elevation of the observatory at Edinburgh. The general form of the plan, as will be therein seen, is a Greek cross, 62 feet long, terminated at its feet by projecting hexastyle porticoes, which are 28 feet in front, and surmounted by pediments. The intersecting limbs of the cross at their intersection are covered by a dome 13 feet diameter, which traverses round horizontally, and under its centre a pier of solid masonry is brought up of a conical form 6 feet in diameter at the base, and 19 feet high. This is intended for a portable astronomical circle or for an equatorial instrument for observations of the heavenly bodies made out of the meridian. In the eastern foot of the cross (*bb*) are stone piers for the reception of the transit instrument; *c* is the stone pier to which the transit clock is attached; and *d* is a stone piece on which an artificial horizon may be placed, when observations are taken by reflection: this is covered by a floor board when

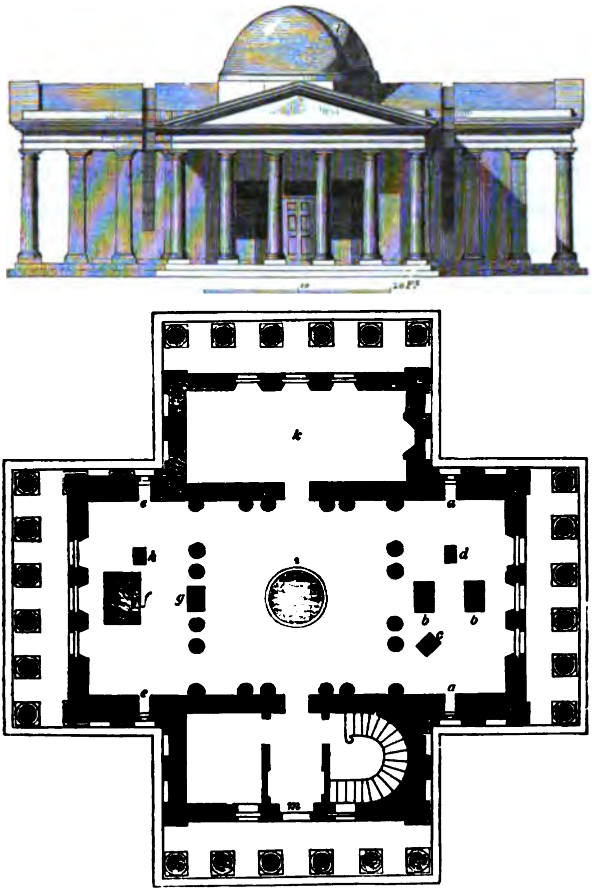

Fig. 1051.

not in use, being just under the level of the floor; *aa* are the slits or chases running through the walls and roof, but closeable by means of shutters when the observation is completed. On the western side (*ee*) are chases as in the transit room; *f* a large stone pier for the reception of a mural circle; *g* the clock pier; *h* the pier for an artificial horizon as before; *i* is the conical pier above mentioned, over which the moveable dome is placed, having an opening (*l*) in the elevation for the purpose of observation; *k* is the observer's room; and *m* the front entrance.

2922. It is to be especially observed that the piers for the reception of the instruments must not be in any way connected with the walls of the building; they should stand on the firmest possible foundation, which, if at all doubtful, must be formed with concrete, and the piers should, if possible, be out of a single block of stone; but if that cannot be obtained, the beds must be kept extremely thin; partial settlement being ruinous to the nicety of the instruments as well as to the observer's business. The observation applies also to the clock piers, all vibration and settlement being injurious also to them. At the Campden Hill observatory, near Kensington, belonging to Sir James South, there is a traversing dome 30 feet diameter in the clear.

2923. A dry situation should be chosen for the site, for, except in the computing rooms, no fire heat can be allowed; and it is important that the brass whereof the instruments are made should not be corroded by the action of moisture. In large public observatories there should be the readiest access from one part to another, and rooms for a library and computers independent of the chief astronomer's room.

Sect. XII.

LIGHTHOUSES.

2924. It may perhaps be thought that we are touching on the province of the engineer in devoting a section to lighthouses; but we cannot forego the completion of the previous section by some few observations on lighthouses, which are the handmaids to the important results which flow from observatories, being the spots which verify the course of the navigator, and serve as precautions for his guidance when near the shores of a country.

2925. The lighthouse dates from the earliest period; and without entering into the question whether the ancient lighthouses were dedicated to the gods, or whether the towers erected for the purpose of warning the mariner were nautical colleges, where astronomy and the art of navigation were perfectly taught, we may at once proceed to state that in the earliest times they appear to have consisted of a tower of masonry, sometimes of a circular form, but usually square, and consisting of various apartments, as the establishment was greater or less, wherein was a raised altar upon which the beacon was established.

2926. Those who wish to pursue the history of the lighthouse must be referred by us to Jacob Bryant, whose theory is so pleasant that to it we must apply the old Italian saying, "*Se non è vero è ben trovato.*" We therefore leave the reader to consult our author on the subject of the purait or fire-towers. So also we shall not touch upon their perversion, nor the alleged dissoluteness and barbarity of the priests and priestesses who had the care of them, which we believe to be fables.

2927. Certain however it is that the whole of the ancient establishment of fire-towers or lighthouses at an early period common on the shores of the Mediterranean, the Archipelago, the Bosphorus, and Red Sea, have long since disappeared. Among the most celebrated of these was the Pharos of Alexandria, which has given its name in French and Italian to all lighthouses. It was accounted one of the seven wonders of the world, and, in history at least, has perpetuated the glory and name of its founder, Ptolemy Philadelphus. If Pliny may be relied on, it was the work of Sostratus, 300 years before the Christian æra, and bore an inscription to the following effect: "Sostratus the Gnidian, the son of Dexiphanes, to the gods preservers, for the benefit of those who use the sea." Lucian, however, says that this inscription was craftily covered with plaster, on which the name of Ptolemy was inscribed, but that the decay of the plaster left the name of Sostratus only. The story is however improbable, and is dependent entirely on the authority of the satirist. The dimensions of this building are not satisfactorily known: some have said its height was 300 cubits, or 100 times the height of a man, which would assign to it a height of 550 feet. On its top a fire was constantly kept, which, according to Josephus, was seen at the distance of three hundred stadia, equal to about forty-two British miles, which is a reasonable account; but those who have delighted in marvellous stories have made the distance one hundred miles, and others have wonderfully gone beyond the last by assigning seven hundred miles as the distance, from which the speculum used distributed light! That this work was one of extraordinary magnificence cannot be doubted; the cost has been stated at 800 talents (300,000*l.* sterling); and there is reason to suppose that it was *quasi* the parent of all others: but all we have said must be taken with great allowance, except that we believe it was a splendid monument of the time.

2928. We have thus far extended in this case our observations, not perhaps in very strict accordance with the plan of this chapter, which relates rather to principles than history; and the only excuse we offer is, that we know not where in our work they might have been more appropriately introduced. We perhaps may not better satisfy the reader in what follows; which, from the nature of the subject, must be more instructive from what has been actually executed than from the general principles upon which the construction of a lighthouse depends.

2929. The most architectural of modern lighthouses is that of Corduan on the coast of France, which stands on a large rock, or rather on a low island, about three miles from land, at the entrance of the river Garonne. Like that of Alexandria, this lighthouse seems to have been intended for the commemoration of an æra in the history of France from the eminent utility of the building and the magnificence of its structure. Founded about the year 1584, in the reign of Henry II. king of France, it was carried on under the reigns of three successive monarchs, arriving at its completion in 1610, in the reign of Henry IV. It stands upon a platform of solid masonry, and is surrounded by a parapet about 145 feet in diameter, which is equal to the height. The lightkeepers' apartments and store rooms are not in the main tower, but form a detached range of buildings on the great platform, the interior of the tower itself being finished in a style of magnificence too splendid for the use of common persons. Over the fuel cellar, which is formed in the solid masonry of the platform, is the great hall, 22 feet square, 20 feet high, with an arched ceiling. On this floor are two wardrobes and other conveniences. Above the last-mentioned room is the king's room, 21 feet square and 20 high, with an elliptical ceiling, There are on this floor a vestibule, two wardrobes, and other conveniences. On the third floor is placed the chapel, for a priest who occasionally says mass is attached to the establishment, and this is 21 feet in diameter, domed, and 40 feet high, and lighted by eight windows. There is an eye in the dome through which is seen the ornamental roof of the room above, and that is 14 feet diameter and 27 feet high. This is used by the lightkeepers as a watch room. Over it rises an apartment, which is immediately under the light room, used for holding sufficient fuel for one night's consumption, and capable itself of being converted into a place for the exhibition of a light in case of repairs being required to any extent in the main light room, which, as we have said, is immediately over it, and is surrounded by a balcony and circular stone parapet. The height from the floor to the top of the cupola of the original lantern or light room was 17 feet, and being unglazed, the smoke was carried out on either side in the direction of the wind. The roof, moreover, formed a kind of chimney in the form of a spire, terminating with a ball. The height of the light room, which was entirely of stone, was 31 feet from the light room floor to the ball on the top of the spire. The fuel first used for the light was oak, after which pit coal was introduced; but in modern times lamps and reflectors have succeeded the last, and the light is now seen at a proper distance.

2930. In England the student may turn to the Eddystone lighthouse, by the celebrated Smeaton, not only as an object of great beauty, but of that soundness of construction, which is the most essential requisite in works of this kind. The general form is seen in fig. 1032. This is a fine illustration of fitness producing beauty. The resistance it affords against the waves arises from the beautiful curved line which leads them up it instead of being broken against it. Indeed, in stormy weather, the waves actually roll up the side, and fall in a contrary curve over the top of the lighthouse. The beds of the masonry are so laid and dovetailed and joggled into the rock itself as to become a part of it. The foundation stone of it was laid on the 12th of June, 1757, and it was first lighted on the 16th of October, 1759. A narrative of the work was published by Mr. Smeaton, to which for detail the reader is referred. The two lower stories are used as store rooms; the next above serves for the kitchen, above which is the bedroom, over which is the light room.

2931. Thus, we see, there is no reason why lighthouses should not be beautifully formed structures, instead of absurd misshapen masses of masonry, as they generally are. The attempt to make them resemble columns is intolerable; they should possess, according to the different situations, a character peculiar to themselves: hence the application of a column for the purpose is the worst of abuses. The North Foreland lighthouse, whose plan is polygonal, would be a good example had the details been properly attended to in the design. We do not here touch upon the mode of lighting, which has of late years occupied much attention, having considered the duty of the architect performed when he has provided a beautiful, lasting, and secure fabric for the reception of the lights.

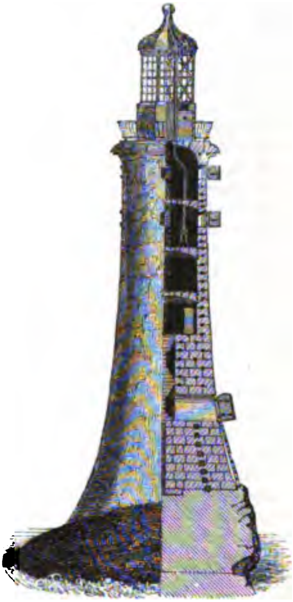

Fig. 1032.

SECT. XIII.

ABATTOIRS OR PUBLIC SLAUGHTER-HOUSES.

2932. It may be thought unnecessary to assign a section in this work to the consideration of a species of building unfortunately unknown to this country, in which its non-employment is truly a reproach. The improvements still in progress however in the metropolis justify, we hope, the expectation that the paltry interests of a particular class, and the disgraceful opposition of the corporation of the city of London, will not much longer prevail to prevent the removal of Smithfield market, and the establishment of public slaughter-houses or abattoirs round the different outskirts of the metropolis. It is the duty of the legislature to interfere and stop the danger and unwholesomeness of the present practice, and not to leave it to individuals to improve the comforts and security of London and its suburbs. The cemeteries established by companies have done much: we hope to see the day when the subject in question will be forced on the government, without respect to the corporation tolls of the market at Smithfield.

2933. The accidents arising from overdriving cattle through the narrow streets of Paris, and the infectious effluvia from the slaughter-houses often causing contagious maladies in their neighbourhood, induced the French government, in 1811, to execute a project which had been entertained for nearly a century previously, that of removing all the slaughter-houses from the heart of their capital. The result of this determination has been, not only the prevention of all cause of complaint of the former inconveniences, but has produced a set of buildings bearing a character of grandeur and magnificence proportionate to their destination. It was a worthy exercise of the power of the government; it has obviated the disgraceful sights almost every day witnessed in London, sights tending to deprive the lower classes of humanity, and to render them ferocious, to corrupt the mind, to offend the eye, and to injure the public health. Without strictly adhering to the term abattoir, which would more properly signify a slaughter-house where the cattle are slaughtered, we mean by our proposition, not only the place for killing the cattle, but an establishment where, after they are killed, under the inspection of proper officers, the skins are arranged for sale, as well as the tallow obtained from the fat, before these are distributed to the respective trades.

2934. Political economists have doubted whether an individual ought to be restricted in the exercise of his industry wherever he may think it most conducive to his interest; we are however inclined to apply to the principle the maxim of the lawyers, "sic utere tuo ut alienum non lædas," and think that disagreeable and unwholesome establishments should be removed from all large cities. The experiment however, at all events, has been most successfully made in Paris, where butchers are no longer allowed to kill their cattle, except in the public abattoirs. For the purpose five open airy spots have been selected in the outskirts of the city, corresponding in size to the demand of those parts of the town to which they are correspondent. Those of Menilmontant and of Montmartre are the most considerable and extensive; but the rest are constructed on similar plans, in which there is no difference except in the number and extent of the buildings. We shall therefore describe generally the first named, that of Menilmontant.

2935. The slaughter-house of Menilmontant at Paris is situated on a declivity, which contributes to its good drainage, and the consequent salubrity of the establishment. It stands on a site about 700 feet by about 620 feet, being insulated between four streets. Through an iron railing, about 108 feet in extent, flanked by two lodges, or *pavillons*, in which are accommodated the officers of the establishment and their *bureaux*, is the principal entrance of the edifice. On entering from this a large square space presents itself, from the centre whereof may be seen the whole of the buildings, twenty-three in number, composing the abattoir. This court is about 315 feet broad, and on its great sides about 475 feet long, and on its right and left are four double buildings, separated by a road which traverses the whole ground parallel to the principal façade. These are the slaughter-houses, each whereof is about 200 feet long by 136 feet in breadth, and they are separated by a paved court, in the direction of their length, so inclined as to carry off the filth, such court dividing them into two piles of building, each of which contains eight slaughter-houses for the particular use of the butchers. Each slaughter-house is lighted and ventilated from openings in the front walls. Above them are attics for drying the skins and depositing the tallow, and to keep them cool the flat roofs project very considerably. Behind the slaughter-houses, and parallel to them, are two sheepfolds, and at their extremities two stables, each of which contains lofts for the hay, and on each side of the court complete the two masses of building which compose the design. At the end of the court is a convenient watering place, and two folds for the first distribution of the cattle; and also two insulated buildings for melting the tallow. These are intersected by a broad corridor, giving access to four separate melting-houses, with vaulted cellars, which serve as coolers. Beyond these, parallel to the enclosing wall, are two long buildings, divided into many warehouses on the ground and first floor, and standing on cellars, in which the undressed leather is kept, the upper floor being destined for the reception of calves' and sheep skins. The last point to be noticed is a large double reservoir of water, of masonry, carried on two series of vaults, which serve as stands for carriages. A steam-engine between the two basins pumps the water into the reservoir. The basins are about 323 feet in length. Happe was the architect; and the cost was something above 120,000*l*. The rent which some years ago the five establishments yielded to the city was about 12,000*l*. per annum.

2936. The description we have given shows the general distribution of the buildings, which are the subject of the section. Although general, we apprehend that, with the particular information of which in every case the architect must possess himself, enough has been said on the subject.

Sect. XIV.

EXCHANGES.

2937. An exchange is a place of meeting and resort for the merchants of a city to transact the affairs relating to their trading. We are not aware that the ancients had any edifices exactly in their destination resembling the modern exchange, as used by us in these days; there is, indeed, every reason to believe that the ancient basilica served at the same time for the accommodation of the officers of the law and for the assembling of the merchants.

2938. All modern cities with any pretension to commerce have some place appropriated to the reception of the merchant, to which at a certain hour he resorts. Sometimes we find it a place surrounded with porticoes and planted with trees. Often it is a building, including several porticos on the ground floor, surrounded by offices for the bankers and money-changers, which latter use has given among us the name of exchange to the building.

2939. The Exchange at Amsterdam seems for a long time to have prevailed as the model for all others. It was commenced in 1608, and finished in 1613, and its architect was Cornelis Dankers de Ry. It is about 271 feet long, and about 152 feet wide. The whole edifice is supported on three large arches, under which flow as many canals. On the ground floor is a portico surrounding a court, above which are halls supported on forty-six piers. The divisions which they form are numbered and assigned each to a particular nation or class of merchants. In the court, and within the enclosure, is the place of meeting for mercantile affairs. At the top is another large hall, and a warehouse for various kinds of merchandise.

2940. The exchange is, perhaps, next in importance to the cathedral of the city, and should be commensurate in appearance and accommodation with its wealth and consequence; it should, moreover, if possible, be placed in the most central part. Such was Sir Christopher Wren's idea in forming the plan of London after the conflagration. He considered the forum of the ancients to be the true model upon which a modern exchange might be engrafted, and we think he was correct. Any edifice which in appearance resembles an ancient temple is unfit in character, and shows puerility and poverty of imagination in the designer. Porticoes are the principal features of such a building, and the variety in which they may be used for the purpose is infinite, and will afford ample scope for the artist's talent.

2941. No offices or shops, as about to be constructed in the new Royal Exchange, for the purpose of obtaining rent, should be connected with the fabric, save only as in Paris, for example, a *Tribunal de Commerce* with its accessories, an establishment much wanted in England; and perhaps in addition to this, in a maritime country like ours, a large hall and offices for the transaction of business relating to the shipping interest.

2942. In London and other places it has been usual to leave the court of resort open to the heavens; an absurd practice, which, we suppose, because it was so before, has been re-adopted in the exchange about to be rebuilt in this city. The French are wiser, and though the weather is, generally speaking, much finer in France than it is here, they build their exchange with a roof, for the comfort of those that use it. If, however, our merchants prefer exposure to the inclemency of the seasons, it is not our business to complain of the fancy.

2943. As we consider the Bourse at Paris an admirable model, both in distribution and design, we shall briefly here describe it. The edifice in question was begun in 1808, under the designs of Brongniart, and completed by Labarre at a much protracted period. The general form on the plan is a parallelogram of 212 feet by 126 feet. It is surrounded by an unbroken peristyle of sixty-six Corinthian columns, supporting an entablature and attic. The peristyle forms a covered gallery, to which the ascent is by a flight of steps extending the whole width of the western front. The intercolumniations on the walls are filled in with two tiers, one above the other, of arched windows, separated by a Doric entablature, and surmounted by a decorated frieze. The roof is formed entirely of iron and copper. In the centre of the parallelogram is the *Salle de la Bourse*, or great hall, 116 feet long and 76 feet broad, wherein the merchants and brokers assemble. The Doric order is that used with arcades round the sides, and between the arcades are inscribed the names of the principal mercantile cities in the world. The ceiling is formed by a cove, and in the centre a large skylight serves for lighting the great hall just described. It is rich in sculpture, and decorated with monochrome paintings, to imitate bassi relievi, sixteen in the whole, that is, five on each long and three on each short side. They are all allegorical. The hall conveniently contains 2000 persons. At its eastern end is a circular space railed off for the convenience of the *agens de change:* these only are admitted within it, and to it there is a communication from their hall of business. On the right are rooms for the committee and syndicate of the *agens de change*, for the *courtiers de commerce*, and a hall of meeting for the latter. On the left is an ample staircase leading to the gallery, supported by Doric columns, and to the hall of the Tribunal de Commerce, with its several apartments and waiting rooms. From the gallery, as on the ground floor, a corridor extends round the Salle, communicating with the Chamber of Commerce, the Court of Bankruptcy, and other public offices. The cost of this very elegant and splendid building was about 326,000*l.*; but the merchants and city of London disgrace themselves by allowing 150,000*l.* for a similar purpose here; and even for this sum they cut up their building into little slices, to reimburse themselves by rents for the miserable outlay. So much for the spirit and liberality of the British merchant!

Sect. XV.

CUSTOM-HOUSES.

2944. It is almost unnecessary to inform our readers that a custom-house is an establishment for receiving the duties, or, as they are called, customs levied on merchandise imported into a country, as well as of regulating the bounty or drawback on goods exported. According, therefore, to the importance and wealth of a city, the building to receive it is of considerable consequence. The first point that immediately presents itself is, that it should be provided with spacious warehouses for holding the merchandise which arrives, and in which it is, as it were, impounded till the duties are paid; and next, that there must be provided ample accommodation for the officers who are to supervise the levying of the imposts. Now, these being the data, it is manifest that there can be no building so subject to modification in every respect as a custom-house, and that that which might be well suited to a small town or city, looking to its trade, would be ridiculous either in excess or smallness in another. Yet there are general principles which should guide the student in designing the smallest as well as the largest establishment of this sort, and these are contained in the two maxims, of ample capaciousness for the merchandise to be received into the warehouses, and a panoptical view, on the part of the proper officers, of that which passes in the establishment. Without these requisites, a custom-house is an ill-planned building; but it is not to be supposed that such an observation can apply to an establishment of this nature in a metropolis like London, the subdivisions and details of whose commerce have found as yet all the delegations of the customs in the various docks and sufferance wharf still even too small for the commerce of the country, and have induced the government to extend the collection of the dues beyond the central establishment. We must, however, return to the custom-house calculated for a port of ordinary size, and not that of a metropolis like London, though presently we must refer to what on that has been thought necessary for our guidance in smaller matters. Security against fire must be strictly attended to. The warehouses and covered places for examining and stowing the goods should therefore be arched in brick or stone, and should, moreover, be as much as possible on the ground floor. The officers for the public and heads of the establishment may be over them on the first floor. Both of these are, of course, to be regulated in size by the extent of trade in the place. The general character should be that of simplicity; decoration is unsuited, and should be very sparingly employed. The species of composition most suitable seems to be pointed out in arcades and arched openings. The site should be as near as may be to the river or port, so that the merchandise may be landed and housed with as little labour as possible.

2945. The following is a general view of the apartments and offices of the London Custom House. The long room, which is the principal public room for the entries &c., is 190 feet long and 66 wide. This, as well as the rooms next enumerated, are on the first or principal floor, viz. a pay office for duties, treasury, bench officers or commissioners' rooms, secretary's room, rooms for the inspector general, surveyor of shipping, registrar of shipping, surveyor of acts of navigation, strong rooms, comptrollers, outward and inward, surveyor of works; Trinity light office, bond office, board room, chairman's room, committee room and plantation clerk's office. On the ground floor are the following offices: for minute clerks, clerk of papers, petitions, messengers, landing surveyors, wood farm office, tide waiters, tide surveyors, inspectors of river, guagers, landing waiters, coast waiters, coast office long room, coast bond office, coffee office, housekeeper, searchers, merchants and brokers' rooms, comptrolling searchers, appointers of the weighers and office for the plantation department. Besides these apartments there are warehouses for the merchandise.

2946. The above long list will give a notion of what would be wanted on a smaller scale; but on such matters the special instructions on each case must be the guide to the architect in making his design. Many of the above offices would, of course, be unnecessary in a small port, neither would the dimensions be so large as in the example quoted. The staircases, corridors, and halls must be spacious in all cases, the building being one for the service of the public.

SECT. XVI.

THEATRES.

2947. A taste for dramatic representations prevailed at a very early period among the people of antiquity, and this was not diminished by the introduction of Christianity, even when the temples were deserted and paganism seemed extinct. The destruction of these, however, was its concluding triumph. It would be a difficult matter to fix the precise date of the abolition of the pagan theatre, but it seems likely to have resulted rather from the falling into decay of the old theatres than from a disinclination on the part of the people to the pleasure they received at them. It is not, however, the object of this section to trace the history of the theatre; though we think it right to say a few more words on the subject. With the revival of the arts, the taste for scenic representations appeared with the literature on which they are dependent. In Italy we find, therefore, the drama at this period represented in very large enclosures, such as the amphitheatre constructed by Bramante in the large court of the Vatican, whence the taste soon spread over all the nations of Europe.

2948. The pleasure which flowed from this renewal of an ancient art was at first confined to few, and those were either men of learning or select societies, who bore the expenses, and again raised in the country a renewal of a theatre much resembling those of the ancients as respected the form and disposition. To prove this, we need only cite the example of the celebrated theatre at Vicenza, built by Palladio in 1583, and designed in imitation of the ancient theatres. Its form is a semi-ellipsis, whose transverse axis is parallel with the scene, encompassed with fourteen ranges of steps for the spectators. The greater diameter of this ellipse is 97½ feet, and the lesser, as far as the stage, about 57½ feet. At the summit is a corridor of the Corinthian order, which, from the want of ground, could not be detached all round from the external wall. The nine central and the three external intercolumniations, therefore, where the columns touch the external wall, are filled with niches and statues. The stage is designed with two tiers of Corinthian columns surmounted with an appropriate attic. In the front of the stage are three openings through which three avenues of magnificent buildings appear, and at the end of each is a triumphal arch. All these are executed in alto relievo, but are foreshortened and diminished perspectively. A full account of this building, which is well worth the student's attention, is given in *L'Origine dell' Academia Olympica, &c. Opera di Ottavio Bertotti Scamozzi.* Vicenza, 1690. For dramatic representations this theatre is no longer used, and at present it is only recognised as a monument of the extraordinary skill of the architect, and a memorial of the dramatic buildings of its period. The theatre at Parma, built by Aleotti, is another building belonging to the same class, and preserved, like the last-mentioned, as a curiosity.

2949. When, however, the taste for scenic amusements began to spread, the sovereign princes, who alone could support the expense of such establishments, began to make them a necessary part of their palaces; and the theatre, no longer a public and essential building, became what it now is, not an edifice for the reception and accommodation of the whole population of a city at certain periods, but a place which served for the habitual amusement of those who could afford it. The drama again revived, and its history is an index to the edifices that rose for its representation. Becoming thus necessary for the amusement of the better classes of society, the establishment of theatres was undertaken by individuals in almost every city, and competition was the natural consequence. Then began the division of the theatre into different parts, the entry to which was marked by different prices, and the separation of the common people from those of rank and fortune.

2950. Italy does not contain so many theatres, nor of such consequence, as might be predicated from the taste of its inhabitants. Among the earliest of consequence was that built at Bologna in 1763 by Antonio Galli Bibiena, (not to mention that built at Verona under the direction of the celebrated Scipio Maffei by Francesco Galli Bibiena,) with a noble portico in front and salons in the angles, possessing moreover great merit in its interior distribution. In the Italian theatres there is almost invariably a certain feeling of grandeur and unity about the interior little to be expected from the exterior, which in no way leads the spectator to the suspicion of a fine *Salle de Spectacle* behind it.

2951. France has the credit of having erected the first modern theatre that can be denominated an example in this species of monumental architecture. That to which we allude is the theatre at Bordeaux, which is 325 feet in length, and half that measure in width. It is surrounded by arcades, whose piers are decorated with pilasters of the Corinthian order, running up the whole height through the ground and one-pair stories. Set back, an attic is raised, which conceals the roof, wherein the necessary accommodations which a theatre requires are disposed. Whether we consider the exterior or interior of this edifice, everything is grand; the accessories are worthy of the whole, and the richness of the interior decoration is only equalled by the fine forms whereon the decorations are used. The ingress and egress are admirable; and a splendid concert-room and magnificent staircases complete the destination, to which it is so suited, as to afford the finest model of a theatre to which we can refer the student. The plans, &c. of this work were published by the architect, under the title of *Salle de Spectacle de Bourdeaux*, atlas folio, Paris, 1782. Paris but followed Bourdeaux in improving its theatres, and latterly the metropolis of England followed in the wake.

2952. The principal points for the consideration of the architect in the composition of a theatre, may be classed under the heads of utility, suitableness for the purpose, and taste in combining them. Under the first head must be placed the accomplishment of two main objects, those of seeing and hearing what passes on the stage. These, indeed, are intimately connected with each other, and are entirely dependent on the form adopted for the plan of the interior, that is, the general form given to the boxes which surround the part before the curtain. We are not aware of any plan which, in this respect, is not based on a quadrangular, elliptical, or circular form.

2953. The quadrangular form, besides its want of beauty, is not well adapted for fulfilling the objects with which we set out. In this, the greater number of spectators or audience who occupy the side boxes, are so inconveniently placed, that, to observe what is going on, their heads must be turned sidewise, and they are hence in a false position for the object. The actor being generally the point to which all eyes are directed, the spectator close to the proscenium will look at him in a right direction; but as the spectator removes to the extremity of the side, it is manifest that the angle in which the head must be turned becomes sharper, and the position is then painful. Besides this objection, the form is known to be unfavourable to hearing or to the propagation of sound.

2954. The truncated oval is in some measure subject to the same inconveniences on the sides as the last-mentioned figure. It removes also a large portion of the spectators to a considerable distance from the centre of the scene, besides which, in the boxes near the proscenium their seats tend in opposite directions to the actor. It has been to remedy these faults that the form of the horseshoe has been adopted, which is a sort of mean between the quadrangular and oval forms: and where the plot of ground is much longer than it is wide, it is a suitable figure, and one which affords the opportunity of increasing the number ot boxes.

2955. When, however, the circumstances concur in allowing it, the adoption of the semicircular plan is doubtless the best. It is a figure which allows each spectator to be at an equal distance from the scene, that also by which the spectators in adjoining boxes less interfere with one another, that which affords the means of all seeing equally well, that in which the sound is most equally distributed, and that whose uniformity and simplicity seems to engender the best decoration. The semi-elliptic, with the transverse axis parallel to the proscenium, has interior advantages in some respects over the semicircle; but it induces great difficulty in connecting the proscenium itself with the auditory part of the house, and, by increasing the width of the proscenium, increases the difficulty of framing the roof conveniently for the painting rooms, and securely as respects the walls.

2956. Upon the destruction by fire of Drury Lane Theatre, a pamphlet appeared, entitled "Observations on the Principles of a Design for a Theatre," by Benjamin Wyatt, London, 8vo. 1811. These observations are so well worth the notice of the student that we shall close this section by giving the substance of them. The heads for consideration, says the author, are —

2957. *First.* The size or capacity of the theatre, as governed by the width of the proscenium or stage opening; and by the pecuniary return to be made to those whose property may be embarked in the concern. *Second.* The form or shape of the theatre, as connected with the primary objects of sound and vision. *Third.* The facility of ingress and egress, as materially affecting the convenience of those who go to every part of the house respectively, as well as their lives, in cases of sudden accident or alarm. *Fourth.* Decorum amongst the several orders and classes of the visitants to the theatre, as essential to the accommodation of the more respectable part of those visitants, and consequently of great importance to the interests of the theatre. *Fifth.* Security against fire, as well with relation to the expense of insurance as with relation to the lives of individuals going to the theatre.

2958. The size or capacity will necessarily depend very much on the width of the proscenium or stage opening, inasmuch as it is from the extremities of that opening that the form of the theatre must spring. The annexed is a statement of the width of proscenium at the theatres named: —

Argentino, at Rome - - - - -	36 feet.
Covent Garden - - - - - -	38 feet.

Théâtre Italien, Paris (burnt)	38 feet.
Turin	39 feet.
Bourdeaux	39 feet.
Parma	40 feet.
Milan	40 feet.
San Benedetto, at Venice	40 feet.
Théâtre François, at Paris	40 feet.
Drury Lane	40 feet 6 inches.

A width beyond 40 feet seems to be considered by the performers as inconvenient from the space they would have to pass over in the business of the drama. A greater width, indeed, than that stated prevents the easy and secure working of the scenes, for the machinery is increased in magnitude and weight as the height and breadth of the scenes increase. In mere *spectacle* and scenic grouping a reduction in the width of the proscenium reduces the number of extra performers, or supernumeraries as they are called, which become necessary for filling the stage. Again, every additional foot given to the stage opening increases the quantity of canvass used in the scenes, as well as the framing whereon they are fixed.

In the *Edinburgh New Philosophical Journal*, vol. xxvii., there are, by Mr. J. S. Russell, some elementary considerations of certain principles in the construction of buildings designed to accommodate spectators and auditors, well worth the architect's notice. In every large room, says the writer, a perfectly good seat is one in which, without uneasy elevation of the head or eye, without straining or stretching, we can calmly and quietly take any easy position, or variety of positions, which we may be disposed to assume, and yet may in all of them see and hear the speaker with equal clearness and repose, so as to give him patient and undisturbed attention. The object, then, is to ascertain in what manner the interior of a building for public speaking should be formed, so that throughout the whole range which the voice of a man is capable of filling, each individual should see and hear without interruption from any of the rest of the audience, with equal comfort in an easy posture, and as clearly as if no other individual auditor or spectator were present. (See *figs.* 1033. and 1034.) The position of the seats is first investigated. In the usual variety of station and of position, it appears from experiments that the range required for the purpose is more than a foot and less than 18 inches, so that these may be taken as the limits; that is, over the head of the person before you there must be a clear range of 12 or 18 inches, through which the head may be moved upwards or downwards without interruption. In other words, that a straight line drawn from the speaker's head over that of the anterior spectator shall intercept the straight line which forms the back of the seat of the posterior observer, so as to cut off a height of 12 or 18 inches, within which the head of the spectator shall at

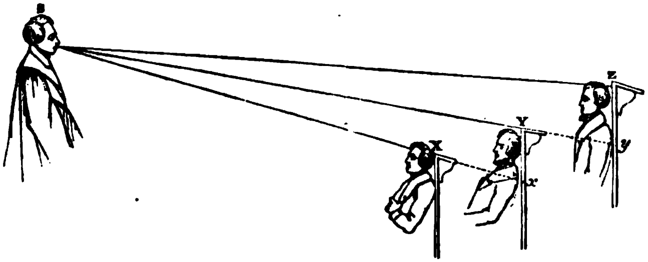

Fig. 1033.

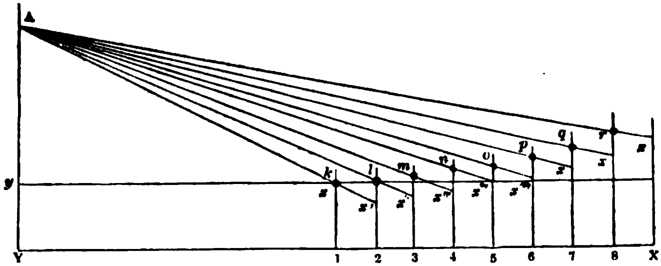

Fig. 1034.

times be comprehended while sitting in a comfortab e position. Thus let S (*fig.* 1033.) be the speaker and XYZ be three successive ascents; then the line SX must fall below SY, so as to leave the space Y*x* = 18 inches = Z*y*.

2959. Applying this formula to every individual place in the room or building, we shall have the form required to satisfy the auditors. Let 2½ feet be assumed as a constant representing the distance of one spectator behind another, measured horizontally; and 1½ feet as the clear space, measured on the vertical line, for the mean range of comfortable vision for each. If the level of the floor, that is, of the lowest seats, be already determined, the form of the interior accommodation may be thus described. AY (*fig.* 1034.), the height of the speaker, YX the level floor. From A*y* take Y*y* = 4 feet. Draw *yx* parallel to YX. Take A*y* to *yx* as 1½ to 2½, that is, as *h*, the range of position of the spectator, to *d*, the distance between the seats. Take horizontal distances 1, 2, 3, 4, &c. = 2½ feet, prolong A*x* to *x*′, then the height *x*′ to *l* = 1½ feet. Join A*l* and prolong it to *x*″, and take a distance *x*″ to *m* = 1½ feet. Through *m* draw A*m*, and prolong it to *x*‴, and take *x*‴*n* = 1½ feet. Continue the process in the same manner to *p*, *q*, *r*, *s*, *t*, &c., and the points will be found of the successive places which the heads of the auditors should occupy.

2960. But it is not only in receding that the back seats must rise; those too far forward may be also unpleasant. They are too low; they also should be raised: but this must be done so as not to interrupt those who are behind. It may be accomplished in a similar way; for, as formerly set off, 1, 2, 3, 4, 5, 6, &c. = 2½ feet (*fig.* 1035.), 1 is the first anterior point. Join A1, and let it cut the vertical line through 2 in *x*″, the portion downwards *x*″*l* = 1½ feet; then *l* is the point found. Join A*l*, make *x*‴*k* = 1½ feet; join A*k* and *x*⁗*i* = 1½ feet; and so on. *g*, *h*, *i*, *k*, *l*, are the places found which the heads of the spectators should occupy, and show the elevation to be given to the seats successively.

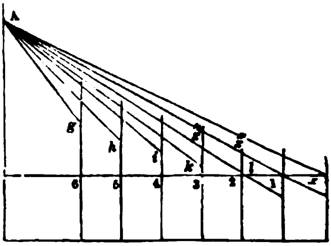

Fig. 1035.

2961. If the simple process described be accurately performed, the points which indicate the places of the spectators will lie in the branches of a very beautiful curve, which may be termed the *iseidomal* or the *isacoustic* curve, that is, *one of equal* seeing or hearing: it will be of the form in *fig.* 1036. A being the place of the speaker, and the heads of the spectators being placed on the line A*mn*, continued as far as the voice will reach, XAX being the axis of the curve, and YY its parameter. This curve has two branches on opposite sides of A, showing that if the building extend behind the speaker, or if the spectacle be visible or the sound audible on every side, the same may be continued all round. By means of this curve, the position of seats in a theatre may be satisfactorily determined.

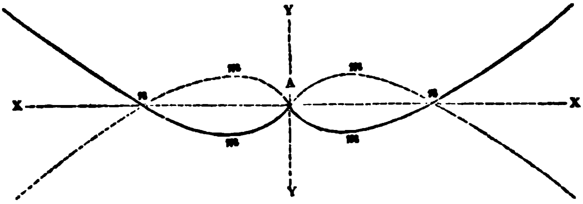

Fig. 1036.

2962. For any great assemblage, where it is desirable that one individual or group of individuals should be seen or heard, an amphitheatre of this form might be constructed from the surface of revolution generated by moving the curve round its axis, which would perfectly accommodate 10,000 individuals.

2963. According to the arrangement of London audiences, Mr. Wyatt calculates that a theatre consisting of three fourths of a circle on the plan, with a stage opening of 35 feet, will contain

78 boxes, in four tiers, and holding - -	1004
4 boxes of larger size, on each side next the stage -	188
A pit, capable of containing - - -	911
A two-shilling gallery - - - -	482
A one-shilling gallery - - - -	284
	2869

2869 persons, exclusive of four boxes in the proscenium, and fourteen in the basement of the theatre, immediately under the dress boxes.

2964. We have already given some general hints relative to the form; we shall here add the author's view of this matter; and thereon he very properly says that, with reference to distinct sound, the safest method is to adopt a form known to be most capable of conveying sound with facility, to construct that form of materials that are conductors of sound, and to avoid all breaks and projections on the surface of that form, because they obstruct and impede the progress of the sound. It is well known that a circular enclosure without breaks possesses the power of conveying sounds with facility, and that wood is an admirable conducting material for the purpose. Count Algarotti, in his treatise on the Opera, says, daily experience teaches us that in a box whose walls are naked, the singer's voice is reverberated in a particular manner; it sounds crude and harsh, and by no means flattering to the ear; the accents are quite lost if the box be hung with tapestry; whereas they are reflected full, sonorous, and agreeable to the ear when the boxes are only boarded, which is an obvious proof, and confirmed by experience, that the best lining for the interior part of a theatre is wood.

2965. Whatever be the form of the theatre, it ought in every part to be limited in extent to such distance as the voice will distinctly reach; and the nearer that figure conforms to the proportions which the natural voice is heard in each direction, the more equally will the sound be heard in every part of the theatre. The experiments tried by Mr. Wyatt proved that the reach of the voice when moderately exerted was in the proportion of about two ninths further in a direct front line than laterally; and that being distinctly audible on each side of the speaker at a distance of seventy-five feet, it will be as plainly heard at a distance of ninety-two feet in front of him, declining in strength behind him so as not to be clearly heard at much more than thirty feet. "According," says Mr. Wyatt, "to these data, it would appear that the geometrical figure, which comes the nearest to the extreme limits of the natural expansion of the voice, is a semicircle of 75 feet radius, or 150 feet in diameter, continued on each side to the extent of 17 feet, or in the proportion of about two ninths of its lateral expansion (*fig.* 1037.) beyond the limits of the semicircle, and then converging suddenly until the two lines meet at C, behind the back of the speaker." But though the voice may be heard at these distances, it does not follow that a theatre of this extent should be erected; indeed, it would be absurd to do so, for the actor varies his place almost every moment; and as he removes from the centre, from which it has been assumed he is speaking, he would become inaudible to some parts of the audience as he receded from it. It is evident, therefore, in planning a theatre, the radius or semi-diameter must be so reduced as to bring the extreme distance at which he may in any case be placed within the space of 75 feet, that is, that when the speaker is placed at the extremity of either side of the stage, his voice may be heard by those seated on the opposite side of the house. In the diagram, the widest part of the theatre inscribed in the larger figure is 58 feet upon the level of the dress boxes; and allowing 9 feet 6 inches for the depth of the boxes on that floor, by means of a projection of 18 inches more than the boxes above, there will be 67 feet 6 inches between the extreme part of the stage on one side and the back wall of the boxes on the opposite side: but as the speaker is in no case placed at either extremity of the stage, and even if so situated, the distance between him and the opposite side of the house would be within 8 feet of the reach of his voice in its lateral direction, and 27 feet within its limits in a direct line; it hence appears that the circular is preferable to any other form; and if we fix a limit for the diameter of that form, we are in possession of the rules which limit the length of the theatre, or the distance from the front line of the stage to the boxes immediately in front of that line. Taking 75 feet for the distance at which the voice can be heard laterally, as the space between the front line of the stage and its immediately opposite boxes may occasionally be in the lateral direction of the voice, the greatest distance from the front wall of the stage to the back wall of the boxes opposite the stage should not exceed 75 feet, the limit of the voice in its lateral direction, because of the turns of head which he must often make for the business of the scene, when that which was opposite might become lateral; and thus those persons sitting in the opposite boxes would be 92 − 75 feet = 17 feet beyond the reach of his voice.

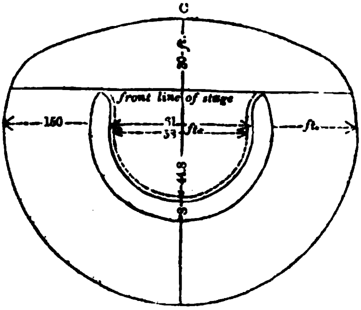

Fig. 1037.

2966. The use of a semicircle without modification would, however, involve the extension of the stage opening to an inconvenient width; and Mr. Wyatt very properly considers that the whole area of a theatre should contain little more than one third of the space over which the voice can reach; "the one," he says, "being (independently of the space behind the back of the speaker) a superficies of 11,385 feet, and the other of 4003." This, he thinks, will compensate for the absorption of sound consequent on the number of the audience, the woollen garments they wear, and the state of the atmosphere, and would ensure a good hearing in every part of the house.

2967. According to the author's statement, he recommends that the distance from the front of the stage to the back wall of the boxes immediately opposite should be about 54 feet; in the old Drury Lane it was 74 feet, and in the old Covent Garden Theatre, built about 1730, it was 54 feet 6 inches. In the Opera House, built by Vanbrugh, it was 66 feet. At Milan it is 78 feet. At the old San Carlos, at Naples, 73 feet; and at Bologna, 74 feet. The distance in the present Covent Garden Theatre is 69 feet 8 inches, or nearly 16 feet more than it ought to have been. How, then, can people wonder at not seeing and hearing in such theatres, where the cupidity of the projectors has overstepped the mark, and very much contributed to the ruin of the drama?

2968. In an opera house the band as it were sustains the voice, and the *spectacle* of the ballet is more addressed to the eye than to the understanding; but even in that the theatre is universally too large for the pleasure of those who appreciate properly what is transacted in the scene. It is satisfactory to know that the theatre which we in our introductory remarks selected as a model should coincide in the main points here in question with Mr. Wyatt's project. We are not certain whether he has visited it, but are certain that if he has he would not change his opinion.

2969. In respect of vision in a theatre, there can be no question that the semicircle gives the best chance for the whole of the audience; but the objections to it are, that it requires that either the stage opening should be of inconvenient width or that the size of the house should be too small. It is therefore, without modification, inadmissible. It is on this account that the ellipse, the horseshoe, and other flat-sided forms, have in later theatres been adopted, though it is manifest that a large proportion of the audience, says our author, "must be placed with their backs inclining towards the scene, and that in *all* of them (if the house be not of extremely *small* dimensions) the front boxes must be at a great distance from the stage; for in proportion as the sides shall approximate each other the front must recede, provided the circumference be not varied." The summing up of the question on this head is thus given by Mr. Wyatt: "There is no object connected with the formation of a theatre which, in all its bearings, is of more importance than that the part of the house which faces the scene should be within a moderate distance from the stage. Unless that be the case, it is obvious that a very large proportion of the spectators must be excluded from a clear and distinct view of that play of the features which constitutes the principal merit of the actor in many of the most interesting scenes." Mr. Wyatt does not believe that the height of the ceiling injures or affects the sound of the voice in the lower parts of the theatre, and observes that it must in every theatre "be much too high to act as a reverberator or sounding board to the lower parts of the house." But we do not agree with him on this point, and think we could refer him to more than one theatre in the metropolis which is defective in the conveyance of the sound from this cause alone. Besides this, we do not feel quite certain that the diagonal line drawn from the actor to the upper tier of boxes should not be the regulating distance, instead of the horizontal one which has been mentioned above.

2970. Ingress and egress should be provided on each side of the house, so that whatever doors, passages, and staircases are placed on one side, there must be corresponding ones on the other. The spectators are thus divided, and pressure avoided. Angles should as much as possible be avoided, as well as steps in passages, for which no excuse can be offered. Doorways ought not to be less than six feet wide, nor should staircases be of less dimensions. In large staircases, which consist of a centre and two side flights, the central one should be equal in width to the side flights added together. In calculating the size, regard should in some measure be had to the number of persons which the part they serve will contain.

2971. It is only in an English theatre that the public have to complain of the admission of the most unfortunate members of the community, and of their subjection to scenes of great indecency. Nothing of this sort occurs on the Continent, whilst here the proprietors of theatres allow the admission of such persons at a reduced rate of payment if they take an admission for the season. As, in this country, it is impossible to exclude any particular class of persons, it would be well so to contrive the access to the dress circle of boxes that it may be arrived at without passing near the saloons, which are generally the resort of the class of people alluded to.

2972. With the exception of the dressings and interior ornaments of the building, and those parts of the stage and machinery which must be made of wood, it would be possible, though perhaps somewhat inconvenient, to erect a theatre, though not absolutely fire-proof, yet very secure against fire. This is, however, a subject not to be treated here; but we ought not to omit that the supply of water from large reservoirs provided in the upper parts of the building, is a precaution which should never be omitted. Pipes may be laid on from them to those parts, such as the carpenters' room, scene room, and painting room, where fires would be most likely to break out, and where, if they did break out, they would be likely to be most dangerous.

Sect. XVII.

HOSPITALS.

2973. The buildings called hospitals are destined for the reception of the sick poor, for insane persons, and sometimes for particular diseases, among which old age may be enumerated, or disability from wounds, &c. in the public service, of which last class are the royal hospitals of Greenwich and Chelsea. There are some for the reception and education of foundlings, and others for the reception and delivery of pregnant women; and the term is sometimes used to denote a building appropriated to poor persons, where they have an allowance for their board and are lodged free; in short, what is otherwise called an almshouse.

2974. The ancients seem to have had no establishments like our hospitals for the sick; neither do they seem to have had asylums for those who suffered in the public service, though at Athens they were fed in the Prytaneum. In Sparta there does not appear to have been any such establishments; neither under the kings, consuls, or emperors of Rome does it seem there was any institution for the reception of poor sick persons. After the establishment of Christianity many hospitals were built by the emperors at Constantinople for poor infants, for aged persons, orphans, and strangers. To the honour of the nations of Europe, no city in it is unprovided with one or more hospitals. In Paris there are thirty-two hospitals, and in London, we believe, some few more. The governments of France, Russia, Germany, and Turkey support these institutions; but in England, with the exception of Chelsea and Greenwich Hospitals, they depend upon the charity and foundations of benevolent individuals, as at Guy's, Bartholomew's, and the other hospitals of London.

There is great reluctance often on the part of the poor to enter an hospital; and on this account we do not think that money ill bestowed which tends to impart to it an agreeable and cheerful exterior. It is almost unnecessary to insist upon a thorough warming, and, what is equally important, ventilation of the edifice: no means should be omitted to render the place wholesome, and to prevent infection spreading from one part to another. If possible, the hospitals of a city should be seated in the least populous parts, if the health of the city be consulted, or on each suburb; in which latter case the establishment would be nearer the quarter it is to serve, and more accessible in a short time in the case of accidents.

2975. The plans of some of the finest hospitals in Europe are given in Durand's *Parallèle d'Edifices;* among them may be mentioned that of Milan as a very fine example of disposition. It is indeed the most celebrated in Italy. A large portion of it remains still unfinished. The architect was Filarete, and, being commenced in 1457, it is of course in a half-Gothic sort of style. The accommodations for the men are on one side of a very large cloistered court, 152 feet wide and 204 feet long, and are in the form of a cross, 304 feet long on each side and 30 feet wide. In the intervals of the cross are four court yards, on whose remaining sides are rooms for the assistants. A canal flowing at the side answers the domestic purposes of the place, and also turns a mill for the use of the establishment. On the opposite side of the cloistral court above mentioned are similar accommodations for the women. And in the middle of the narrow side of the great cloister, opposite the entrance, is a church, which serves for the whole establishment. The cloisters of the large court and the main body of the building are in two stories, so that they form galleries of communications. This edifice has served for model to many others; and though it is now many years since we visited it, its excellence will not easily be effaced from our recollection. The hospital, given by Durand in the plates above quoted, De la Roquette, in the suburbs of Paris, designed by Poyet, was conceived on a magnificent scale, and was admirably planned. In this design each room, as well those on one side of the establishment for the males as those on the other side for the females, is appropriated to one particular disease. Each of these rooms is about 32 feet wide and 30 feet 6 inches high. Behind the beds (which are in two rows in each room) runs a passage about 3 feet 4 inches wide, which removes them so much from the walls, and allows therefore of the necessary waiting on the invalids, and hides the wardrobe attached to each bed in the window recesses. Above these passages, which are about 6 feet 6 inches high, is arranged on each side a row of windows, by which ventilation as well as light is obtained. The ground floor contains the halls and offices necessary for such an establishment. The designs for this building were made about 1788, on the instructions drawn up, after several years' investigation, by a number of the most skilful and learned medical men of France, so as best to unite health and convenience in such an edifice. One of the conditions prescribed by their programme was the complete insulation of each apartment, as well as an easy communication by covered galleries round the building, and these were required to be of such extended dimensions that the air around should be unobstructed and circulating in every part with freedom, thus affording a wholesome promenade for the patients.

2976. The hospitals of Greenwich and Chelsea are good examples for establishments of this nature; the former, indeed, adds to its other excellencies a magnificence in the architecture worthy the object, though not so originally intended. The Hotel des Invalides at Paris is another monument worthy of all praise; and indeed we scarcely know a quadrangle more imposing than the court of this edifice with its double tier of arcades. This hospital contains 7000 veterans, and has attached to it a library of 20,000 volumes. We know not how better to close this section than with the maxims, or rather general observations, of Durand upon the subject: "Dans des hospices," says the author, "dont la disposition répondraient si parfaitement a l'importance de leur objet, on ne craindrait plus de venir chercher des secours. Leur aspect seul, si non magnifique, du moins noble et agréable, influerait sur l'efficacité des remèdes. En entrant dans des tels édifices, où tout annonce le respect que l'on porte à l'humanité, et surtout à l'humanité souffrante, on se sentirait soulagé du poids de la honte, fardeau souvent plus insupportable et plus accablant que celui du malheur même."

Sect. XVIII.

PRISONS.

2977. In considerable cities and towns, humanity, and indeed justice, demands, independent of the injury done to the morals of the public, that the same building which confines the convicted felon should not enclose the debtor and the untried prisoner, as well as him whose offence is not of an aggravated nature. Where there is a mixture of the several classes of those that have violated the laws, the young soon becomes infected by the old offender with whom he comes in contact, and returns to society, after undergoing his punishment, a much worse member of it than he was before his incarceration. In small towns, where there is only one, perhaps small, prison, the separation of the prisoners is more difficult to accomplish; but it ought always to be obtained. We hardly need say that the separation of the sexes in a prison is indispensable.

2978. For whatever class of prisoners a building is erected, salubrity and ventilation are as essential as the security of those confined. The loss of liberty is itself a punishment hard to endure, without superadding the risk of disease and death in their train, to persons who may be even innocent of the crimes with which they are charged. Besides which, the disease engendered in a gaol called the prison fever may spread into the city and carry off its inhabitants.

2979. We shall here place before the student the principal requisites which the celebrated Howard has specified for prisons. "A county gaol, and indeed every prison, should be built on a spot that is airy, and, if possible, near a river or brook. I have commonly found prisons near a river the cleanest and most healthy. They generally have not (and indeed could not well have) subterraneous dungeons, which have been so fatal to thousands; and by their nearness to running water another evil almost as noxious is prevented, that is, the stench of sewers. I said a gaol should be near a stream; but I must annex this caution, that it be not so near as that either the house or yard shall be within the reach of floods." . . . "If it be not practicable to build near a stream, then an eminence should be chosen; for as the wall round a prison should be so high as greatly to obstruct a free circulation of air, this inconvenience should be lessened by rising ground, and the prison should not be surrounded by other buildings, nor built in the middle of a town or city. That part of the building which is detached from the walls, and contains the men felons' wards, may be square or rectangular, raised on arcades that it may be more airy, and have under it a dry walk in wet weather. These wards over arcades are also best for safety; for I have found that escapes have been most commonly effected by undermining cells and dungeons. If felons should find any other means to break out of the raised ward, they will still be stopped by the wall of the court, which is the principal security; and the walls of the wards need not then be of that great thickness they are generally built, whereby the access of light and air is impeded. I wish to have so many small rooms or cabins that each criminal may sleep alone; these rooms to be ten feet high to the crown of the arch, and to have double doors, one of them iron-latticed for the circulation of air. If it be difficult to prevent their being together in the daytime, they should by all means be separated at night. Solitude and silence are favourable to reflection, and may possibly lead to repentance." . . . "The separation I am pleading for, especially at night, would prevent escapes, or make them very difficult, for that is the time in which they are generally planned and effected. Another reason for separation is, that it would free gaolers from a difficulty of which I have heard them complain: they hardly know where to keep criminals admitted to be evidence for the king; these would be murdered by their accomplices if put among them, and in more than one prison I have seen them for that reason put in the women's ward. Where there are opposite windows they should have shutters, but these should be open all day. In the men felons' ward the windows should be six feet from the floor; there should be no glass, nor should the prisoners be allowed to stop them with straw, &c. The women felons' ward should be quite distinct from that of the men, and the young criminals from old and hardened offenders. Each of these three classes should also have their day room or kitchen with a fireplace, and their court and offices all separate. Every court should be paved with flags or flat stones for the more convenient washing it, and have a good pump or water laid on, both if possible; and the pump and pipes should be repaired as soon as they need it, otherwise the gaols will soon be offensive and unwholesome, as I have always found them to be in such cases. A small stream constantly running in the court is very desirable. In a room or shed near the pump or pipe there should be a commodious bath, with steps, (as there is in some country hospitals,) to wash prisoners that come in dirty, and to induce them afterwards to the frequent use of it. It should be filled every morning, and let off in the evening through the sewers into the drains. There should also be a copper in the shed to heat a quantity of water sufficient to warm that in the bath for those that are sickly. There should also be an oven: nothing so effectually destroys vermin in clothes and bedding, nor purifies them so thoroughly when tainted with infection, as being a few hours in an oven moderately heated. The infirmary or sick ward should be in the most airy part of the court, quite detached from the rest of the gaol, and raised on arcades. These rooms should never be without crib-beds and bedding. In the middle of the floor of each room there should be a grate of twelve or fourteen inches square, covered with a shutter or hatch at night. The sewers or vaults of all prisons should be in the courts, and not in the passages, and (like those in colleges) close boarded between the seats up to the ceiling, the boards projecting ten inches before each seat. The infirmary and sheds will not render the court unsafe, provided the walls have parapets or small *chevaux de frise.* Debtors and felons should have wards totally separate; the peace, the cleanliness, the health and morals of debtors cannot be secured otherwise. The ward for men debtors should also be over arcades, and placed on one side of the gaoler's house. This house should be in or near the middle of the gaol, with windows to the felons' and to the debtors' courts. This would be a check on the prisoners to keep them in order, and would engage the gaoler to be attentive to cleanliness and constant washing to prevent his own apartments from being offensive. A chapel is necessary in a gaol. I have chosen for it what seems to me a proper situation. It should have a gallery for debtors or women; for the latter should be out of sight of all the other prisoners, and the rest may be separated below."

2980. The above general principles are excellent, and are followed in all gaols of modern construction. The tread-mill is also introduced for punishment, as well as occasionally workshops for trades, to avoid the idleness of the prisoners. Society owes a debt of infinite magnitude to the benevolent man from whom the foregoing quotation has been taken.

2981. One of the most celebrated prisons on a panoptical system in Europe is the celebrated house of correction at Ghent. It is situated on the north side of that city, on the Coupure canal, which is bordered by a double row of large trees. A plate of the plan is given, No. 28. Durand's *Parallèle d'Edifices.* It was begun in 1773, under the reign of Maria Theresa, and is in the form of a slightly elongated octagon, in the centre whereof is a spacious court, which communicates with the different quadrangles of the edifice. Each quadrangle or ward (eight in number) has a yard, and in the centre of that, belonging to the female ward, is a large basin of water, in which the female prisoners wash the linen of the whole establishment. Each prisoner sleeps alone, in a small but well-aired room, and is employed during the day in working at the trade or business to which he or she is competent. Of the produce of such labour, government retains one half when the prisoners are detained merely for correction, six tenths when condemned to a term of imprisonment under martial law, and seven tenths when they have been sentenced to hard labour. The remainder is divided into two portions, one given weekly to the prisoners for pocket money, the other given to them on the expiry of their imprisonment, to assist their reestablishment in society. Religious service and instruction are provided; and if prisoners are destitute of the first elements of knowledge, they are taught reading, writing, and arithmetic, besides receiving other instruction. Solitary confinement is the punishment for insubordination or refractory conduct. The shops for refreshments sold to the prisoners are strictly regulated by the officers of the institution; and the profits resulting from the sale of the different articles are reserved for rewarding the most industrious and best-behaved prisoners. The new part of the building, which has recently been completed, has cost 40,000*l.* sterling; and the whole edifice, when finished, and there is much still to be done, will contain 2600 prisoners. The defect in the institution lies in the reception of unfortunate and criminal persons of all descriptions, from the simple mendicant to the hardened murderer. It is true that those confined for heinous crimes are separated from those who have been guilty of misdemeanours; but the knowledge, on the part of all its inmates, that they to a certain extent are considered in the same predicament, must necessarily so operate on their minds as to throw down the barriers between misfortune and crime, as well as between those who are only commencing a guilty course and those who have consummated their vicious career. The Penitentiary at Milbank, in London, has been erected in some measure on the principles of the house of correction at Ghent, but its inmates are such only as have received the sentence of a criminal court. Where, indeed, the population is so great as in the metropolis of England, prisons for each class of offenders should be provided, at whatever cost. It is a duty due from the government to humanity to see that this is done.

Sect. XIX.

BARRACKS.

2982. Barracks, or buildings for the reception of the military, were common with the Romans, amongst whom they were called *castra* or camps. There were many of these at Rome and in the provinces; but the most perfect remains of Roman barracks are at Pompeii, of which sufficient remains exist to give us a general idea of their distribution. The distribution was in an oblong, and the quadrangle or parade was surrounded by a covered gallery on columns. From this gallery was the entrance to the rooms of the soldiers, but it also served as an ambulatory for exercise. Beyond the further end, opposite the entrance, was a theatre. A more perfect knowledge, however, than we have of the barracks of the ancients, would not assist us in providing better for the military in these days; indeed, there is little required to be said in this place on the subject, inasmuch as in respect of healthy situation, perfect ventilation, and security against fire, the principles which chiefly regulate the disposition and distribution of a hospital, are equally applicable in building barracks, which are, in truth, *hospitia* for the reception of men in health instead of sick persons. Private soldiers in barracks, however, usually sleep on inclined planes, raised from the floor, and at the head abutting against the wall, instead of being provided with separate beds. In Paris there are no less than thirty buildings used as barracks. The details necessary to be provided are a canteen or public-house, for the use of the privates and non-commissioned officers; a spacious mess-room and separate apartments for the officers, and an infirmary. In cavalry barracks, proper stabling and a riding-house of large dimensions must of course be added. For cleanliness, all the yards should be paved, and the utmost precaution taken for carrying off all filth and waste water by means of drainage into a sewer, having a considerable fall from the place. This will, as much as anything, tend to the healthiness of the building.

Sect. XX.

PRIVATE BUILDINGS — GENERAL OBSERVATIONS.

2983. Private buildings differ in their proper character from public buildings as much as one public building differs in character from another not of the same kind. The ends in both, however, in common, are suitableness and utility. The means are the same, namely, the observance of convenience and economy. The same elements are used in the formation of one as of the other; hence they are subject to the same principles and the same mechanical composition. Distribution, which is usually treated distinct from decoration and construction, and very improperly so, as applied to private edifices, is conducted as for public buildings, that is, as we have said, with a view to utility and economy.

2984. If the student thoroughly understand the true principles of architecture, — if he possess the facility of combining the different elements of buildings, or, in other words, fully comprehend the mechanism of composition, which it has in a previous part of this Book (III.) been our object to explain, nothing will remain for him in the composition of private buildings, but to study the special or particular conveniences required in each. There are some quaint old aphorisms of Dr. Fuller, prebendary of Sarum, which are so applicable to all private buildings, that we shall not apologise for transferring them to our pages.

2985. "First," he says, "let not the common rooms be several, nor the several rooms common; that the common rooms should not be private or retired, as the hall (which is a pandochæum), galleries, &c., which are to be open; and the chambers, closets, &c. retired and private, provided the whole house be not spent in paths. Light (God's eldest daughter) is a principal beauty in a *building*; yet it shines not alike from all parts of the heavens. An east window gives the infant beams of the sun, before they are of strength to do harm, and is offensive to none but a sluggard. A south window in summer is a chimney with a fire in it, and stands in need to be screened by a curtain. In a west window the sun grows low, and ever familiar towards night in summer time, and with more light than delight. A north window is best for butteries and cellars, where the beer will be sour because the sun smiles upon it. Thorough lights are best for rooms of entertainments, and windows on one side for dormitories."

2986. "Secondly, as to capaciousness, a house had better be too little for a day than too big for a year; therefore houses ought to be proportioned to ordinary occasions, and not to extraordinary. It will be easier borrowing a brace of chambers of a neighbour for a night, than a bag of money for a year; therefore 'tis a vanity to proportion the receipt to an extraordinary occasion, as those do who, by overbuilding their houses, dilapidate their lands, so that their estates are pressed to death under the weight of their house."

2987. "Thirdly, as for strength, country houses must be substantives, able to stand of themselves, not like city buildings, supported and flanked by those of their neighbour on each side. By strength is meant such as may resist weather and time, but not attacks; castles being out of date in England, except on the sea-coasts, &c. As for moats round houses, 'tis questionable whether the fogs that arise from the water are not more unhealthful than the defence that the water gives countervails, or the fish brings profit."

2988. "Fourthly, as for beauty, let not the front look asquint upon a stranger, but accost him right at his entrance. Uniformity and proportions are very pleasing to the eye; and 'tis observable that freestone, like a fair complexion, grows old, whilst bricks keep their beauty longest."

2989. "Fifthly, let the offices keep their due distance from the mansion-house; those are too familiar which presume to be of the same pile with it. The same may be said of stables and barns; without which a house is like a city without works, it can never hold out long. It is not only very inconvenient, but rather a blemish than a beauty to a building, to see the barns and stables too near the house; because cattle, poultry, and suchlike must be kept near them, which will be an annoyance to a house. Gardens ought also to be disposed in their proper places. When God planted a garden eastward, he made to grow out of the ground every tree pleasant to the sight and good for food. Sure he knew better what was proper for a garden than those who now-a-days only feed their eyes and starve their taste and smell." The same honest old dignitary (would we had some such in these days!) says, "He who alters an old house is ty'd as a translator to the original, and is confined to the fancy of the first builder. Such a man would be unwise to pull down a good old building, perhaps to erect a worse new one. But those who erect a new house from the ground are worthy of blame if they make it not handsome and useful, when method and confusion are both of a price to them."

Sect. XXI.

PRIVATE BUILDINGS IN TOWNS.

2990. The common houses of the town are not those which will engage our attention. In London, and indeed throughout the towns of England, the habits of the people lead them to prefer separate houses for each family, to one large one in which several families may be well lodged, or, in other words, they prefer rows of mean-looking buildings, with holes in the walls for windows, to the palatial appearance which results, in Paris and most of the other cities in Europe, from large magnificent buildings with courts, and capable of accommodating a number of different establishments. The section will be confined chiefly to the arrangement of a house of the first class; and from what will be said, sufficient hints may be drawn for the composition of those in a lower class.

2991. The private buildings in a town are often in their composition beset with difficulties which do not occur in those of the country, where the extent of site is freer and ampler. These, therefore, may be isolated, and receive light from every side. Their offices may be separated from the main house, and the parts may be disposed in the simplest possible manner; but in cities the site is generally more or less restricted, often very irregular in form, and generally bounded by party walls. Yet, with all these obstacles, it is necessary to provide almost as many conveniences as are required in a country house; whence the disposition cannot be so simple in its application as where there is no restraint. All that can be done is to make it as much so as the nature of the spot will permit, and to produce the maximum of comfort which the site affords.

2992. Nothing must be considered below the attention of an accomplished architect, nor anything above his powers; he ought as cheerfully to undertake for the proprietor the conduct of the meanest cottage as of the most magnificent palace. Little will be requisite to be said on the common houses of London, or other cities and towns in which there are seldom more than two rooms and a closet on a floor, with an opening behind. These may be varied; but the general mode is to construct them with a kitchen in a floor sunk below the ground, and a room behind, serving for a variety of purposes; an area in front, with vaults under the street, and the same often in the rear of the house. The space opposite the descending stairs will form a dark closet; and the privies, and wine and beer cellars, with other small offices, are provided in the vaults. On the ground floor there is rarely more than a passage on one side, which conducts to a staircase; and this requiring more width than the passage itself, the best room on this floor is placed in front, and the back is a smaller room, often opening on a small light closet still further in the rear. A yard is supposed behind, by which light is obtained for the back room. On the one-pair and other floors the passage becomes unnecessary as an access; the drawing or front room therefore runs over it, and becomes larger, capable, in the upper floors, of subdivision for bedrooms, or other purposes, as may be required; and the back rooms, with their closets, if carried up, follow the form of those on the ground floor. Though little variety may be the result of the restricted space to which this species of house is usually confined, the addition of four or five feet either way will enable an intelligent architect to throw in closets and other conveniences which are invaluable, as relieving a small house from the pressure which otherwise will exist in the different apartments. But this will be obvious to the practical man, unless he walks about blindfold. The houses we have just described may stand upon a site of about twenty feet by thirty feet, independent of the vaults in front and rear, and the back light closet, which is an invaluable appendage to a house of this description; which is the scale of a second-rate house.

2993. Of the next higher rate of house the varieties are too great to be described, because the extent of the largest arrives at what would be called a palace on the continent. But, taking a mean between that just described and that last named, we may take one similar to a moderate one in Portland Place for example. In such a one we must provide, on the basement or sunk story, vaults under the street for beer, coals, wood, privies, and the like, the refuse or dust of the house. The body or corps de logis on this floor must contain housekeeper's room, servants' hall, rooms for butler and head footman, wine cellar, closets for linen, strong room for plate, with closets and other conveniences for the household. The ascending staircase must also have a space set apart for it. In the rear, under the open area behind, will be placed a kitchen, scullery, and the larder, with the other appendages of this part of the household; an area, covered, where the communication with the rest of the floor is made between the body of the house and the offices in question. Beyond the kitchen are often vaults (though the disposition is sometimes otherwise), over which the stables and coachhouses are placed, opening on the ground floor or to a mews parallel to the street in which the house is situate. The ground floor of this disposition has usually a dining-room in front, with a good-sized hall at its side, leading to a staircase which ascends in direction of the long side of the house; and this is necessary when the rooms above are to communicate by folding doors. In some old houses, however, the staircase ascends between the front and back rooms, and a back staircase is provided by the side of it. But more commonly this is placed beyond the principal stairs, to allow of throwing the drawing-rooms into one. In rear of the dining-room is often placed a library for the gentleman of the house; and beyond this, and further than the back stairs, when the lateral staircase is used, a waiting-room, at the rear of which a water-closet may be placed, with a door from it to the area over the kitchen; or there may be a communication of this sort from the waiting-room, which may serve the purpose of access to the stables. On the one-pair floor the disposition will be two drawing-rooms, a boudoir over the waiting-room, and beyond this a water-closet. On the two-pair floor two bed-rooms, each with a dressing-room, or three bed-rooms and one dressing-room, and a bath-room and water-closet. Above this four bed-rooms and closets may be obtained; and, if necessary, rooms in the roof in addition. For a good house of this class, with the offices, the plot of ground should not be much less than 100 feet by 30.

2994. Of the first class of houses, as a model may be taken the town-house, in Piccadilly, of His Grace the Duke of Devonshire, which, with the offices and court-yard in front, covers an area extending about 231 feet towards the street, and 188 feet in depth, whereof the house itself occupies a frontage of 163 feet and a depth of 188 feet, and opens on to a large garden in the rear. On the east side of the court-yard are disposed the kitchen and other domestic offices, opposite whereto, on the west side, stand the coach-houses and stabling. The basement of the house contains apartments for the various persons attached to such an establishment. The principal floor to which the ascent is by an external staircase, contains an entrance-hall, 35 feet by 30 feet, and communicates to an apartment on the west side, 33 feet by 22 feet, leading to the south-western corner room, which is 20 feet square. On the north of the last is a room, making the north-west angle of the building, and this is 40 feet by 20 feet. On the east side of this last, and facing the north, is a room 33 feet by 23 feet, and in the centre of the north front, corresponding with the width of the hall, is an apartment 30 feet by 23 feet 6 inches. To the east of the last is a room 33 feet by 24 feet, and east of that, forming the north-east angle, is a small room 20 feet square. Thus far these rooms, seven in number, are all *en suite*, but this is in some measure interrupted by the remainder of the east flank, which is filled with three smaller rooms. To that of them, however, at the south, which is 20 feet square, a passage is preserved, and from that you enter another room, 23 feet by 22 feet, which once more brings you back to the hall. The staircases are between the north and south rooms on each side of the hall. Above this floor are the lodging rooms, &c. The superficial area of all the reception rooms on the principal floor, added together, amounts to 5708 feet.

2995. Burlington-house, in some respects,—for instance, in its beautiful front court,—may be considered superior to that we have just described. It can be hardly necessary to add that, in such edifices, rooms must be provided for steward, butler, housekeeper, stillroom-maid, servants' hall of good dimensions, valets, ladies' maids, &c.; for a muniment room and plate, both of which must be fire-proof. Baths also should be placed on the chamber floor, with other conveniences which will occur to the architect. The rooms for pictures, if possible, should be on the north side of the building. To Lord Burlington the English aristocracy is much indebted for the introduction of the Italian style into their dwellings; for the taste of Jones had almost passed away when the talented nobleman in question gave a new impetus to proper disposition and decoration. Plans and elevations of Devonshire-house are given in the *Vitruvius Britannicus*, which contains other town houses of importance well worth the student's attention.

Sect. XXII.

PRIVATE BUILDINGS IN THE COUNTRY.

2996. Of first-class private buildings in the country, we apprehend we cannot furnish better hints than by describing that of Kedlestone, in Derbyshire, erected for Lord Scarsdale by Robert Adam. There are others which are larger, but we do not think any superior in distribution and effect. The plans and elevations of it are to be seen in the *Vitruvius Britannicus* above mentioned. The main body of the house M (*fig.* 1038.), is about 136 feet by 105 feet; and at each angle are quadrants of communication to the four wings A, B, C, and D, which are each about 70 feet by 54 feet. On the basement story of the main building are a large and small sub-hall in the centre, the former 67 feet 3 inches by 42 feet, and the latter 42 feet by 40 feet 7 inches. On the right of these are disposed a butler's room, 22 feet 6 inches by 17 feet 9 inches; a housekeeper's room, and a steward's room, 30 feet by 21 feet 6 inches. On the left, a bath, a gun-room, 23 feet 9 inches by 23 feet 7 inches; a smoking parlour, 28 feet by 17 feet 9 inches; a boot-room, 22 feet 6 inches by 17 feet 9 inches, besides closets and staircases, &c. on either side. The wing B contains the stables, a chapel, and other apartments. C, sleeping and other rooms, eight in number, with a staircase which conducts to the corridor in the corresponding quadrant. D contains the kitchen and its requisite accessories, and a servants' hall. This wing has also a staircase to its corresponding corridor in the quadrant, which attaches it to the main body. On the principal story, the main body M has at the entrance, which is in the centre, and approached by a noble flight of steps, a magnificent hall, 69 feet 3 inches by 42 feet, at the end whereof is a saloon 42 feet diameter. To the right, entering from the hall, is the principal staircase, beyond which, laterally, is a bed-chamber 33 feet by 22 feet, with its accessories; and on its end, towards the back front, are ante-rooms, and towards the front the dining-room, whence by the corridor is access to the kitchen in the wing D, and from the ante-rooms above mentioned the corresponding corridor on that side leads to a conservatory in the back front of the wing, and the upper part of the chapel. On the left-hand side of the hall, with windows in the left flank of the main body, is the

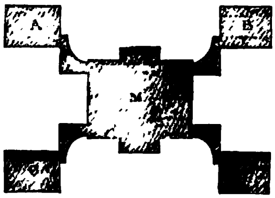

Fig. 1038.

drawing-room, 44 feet by 28 feet; at the end towards the rear is a library, which is continued in the corridor leading to the wing A, wherein is a music *gallery*, 66 feet by 18 feet, with other rooms and a staircase. On the end of the drawing-room, towards the front, is a music *room*, 36 feet by 24 feet, whence the corridor leads to Lord Scarsdale's bedroom, 18 feet square, with dressing-rooms, and the lady's library, which, on this floor, are in the wing C. The wing D is occupied by the upper part of the kitchen, a laundry, 35 feet by 18 feet, and some bedrooms, to which access is by a gallery over part of the kitchen. The main body and wings contain a story over what has been last described, chiefly for chambers. We have before (in the First Book, *figs.* 221, 222.) noticed the splendid hall and salon, which occupy the height of the whole building, and are, though somewhat faulty in detail, very finely-conceived and well-proportioned apartments. The former is 40 feet high to the top of the cove, and the latter 55 feet to the level of the eye of the dome. Though the elevations exhibit defects, we are not inclined to quarrel with them in a dwelling which deserves rather the name of a palace than of a country house.

2997. England abounds with country seats of this class: among them is Holkham, which has already been mentioned in the First Book (511.); but we know none for disposition that can claim superiority over that which we have above described at length, from which the student may derive much information on the requirenda in a mansion of the first class. It is to be understood that we here intend modern buildings. The houses of the times of Elizabeth and James are many of them magnificent structures, but the comfort introduced into houses of later date leaves them, independent of their picturesque beauty, far behind the buildings of Kent, Carr, James, and many others. Blenheim is monumental in its design, and properly so, and hence does not fall within the category of the section.

2998. There are, of course, many intervening degrees between the mansion we have just described and the villa of the retired banker or merchant: it would be impossible to state them in detail. We have given the maximum in the above case, and we shall now give the minimum for the class last mentioned.

2999. The smallest site of ground on which a villa can be well designed is, supposing it an oblong, about 80 feet by 56 to 60 feet. This on the principal floor will admit of a hall, a salon or ante-room, which may lead to the principal apartments, a drawing-room, two secondary drawing-rooms, one whereof may be appropriated to the reception of a billiard table, a good dining-room, not less than 30 feet by 20 feet, a library of equal size, with other rooms, suitable to the particular taste of the proprietor, and the conveniences and accessories which such a building requires. The ground, supposing the domestic offices to be under the principal floor, should be raised, so that they need not be much sunk below the general level of the land. If the building be seated on rising ground, a little more sinking may be allowed than under other circumstances, provided the lower story be protected by dry drains all round the building, to prevent the earth lying against the walls, because drainage, the most important of all things in a building, may then be obtained easily by the natural fall of the ground. The plot we have mentioned will admit of all the offices below, which are necessary for the service of a good-sized family, and above, with only one story above the principal one, will afford a pretty fair allowance of dormitories; but if a concealed story for servants be practised in the roof, there are few establishments on a common scale for which, on the plot, accommodation may not be provided by a skilful artist. The stables and coach-houses and the greenhouses should stand apart. Some persons like to have these communicating with the villa itself; but the practice is destructive of symmetry, and very injurious (except in the villa on an irregular plan, which then rather approaches to the *cottage orné*) to the general effect of the architecture.

3000. The villas at Foot's Cray and Mereworth, imitations of Palladio's Villa Capra, so often mentioned in this volume, and represented in *fig.* 1018., are the maxima of villas: beyond this the villa becomes a mansion, and must be treated as one on a scale more or less grand, as the means of the proprietor allow the architect to provide for his wants. All precepts, however, on this head are valueless, because the architect is regulated so much by the convenience required. He must possess himself fully of that, and, attending to the general rules given throughout the work, but especially in this Third Book, he will find little difficulty in fulfilling the commission with which he is intrusted. Among other matters let him well inform himself of what has been done, and make himself master of the points involved in domestic economy, from the lowest to the highest grade, and he cannot, using that information, fail of giving his employer that satisfaction which is the first care that should animate him.

3001. It is not our intention to touch upon the *cottage orné*, as it is called. This is a nondescript sort of building, subject only to rules which the architect chooses to impose upon himself. The only point to be attended to, after internal comfort has been provided for, is to present picturesque effect in the exterior. It is a branch of practice requiring a minimum of mind on the part of the architect, and for the successful execution of which the landscapes of Gaspar Poussin will give him enough hints to stud a province with them.

Sect. XXIII.

FARM-HOUSES.

3002. The mere building denominated a farm-house is simple enough in its distribution, and scarcely justifies a section here, because the persons engaged in agriculture have generally the best notion of the mode of suiting it to their own particular business and the nature of the farm they occupy. It is first to be considered whether it is expedient to place it close to the other buildings of the farm, such as the barns, stables, and stalls for cattle, &c. If so, it should be designed in character with them, and a large space of ground is enclosed for the formation of a farm-yard; which, notwithstanding the seemingly repulsive nature of the subject, may be made a very picturesque composition as a whole. The farm-house itself, though it must be sufficiently large to accommodate the family of the farmer, should be restricted in the size of its rooms and the extent of its plan by the magnitude of the farm, it being altogether an absurdity to plan a large house on a small farm, not only because of the original cost, which the rent of the land will not justify, but because of the cost of the annual repairs which a large building entails beyond those of a smaller one. The same observation applies to the farm buildings themselves, which in extent must be regulated by the size of the farm cultivated. It is moreover to be considered, in respect of the latter, whether the farm be grazing or arable. In the first case more provision of cattle sheds must be afforded; in the latter case more barns must be allotted to the cultivator. These, however, are matters upon which the architect receives his instructions from the proprietor, and whereon, generally speaking, he is himself incompetent to form a correct judgment.

3003. In the commonest farm-houses the external door may open to a plain passage, at the end whereof the staircase may be placed. On one side of the passage may be a common kitchen, and on the other side the better or larger kitchen, serving also as a parlour for the farmer and his family. Beyond these, on one side, may be placed the pantry, and on the other side the dairy-room, the last being much larger than the former, and being on the side of the parlour or best kitchen, not so liable to the heat. To these, as needful, may be added more rooms on the ground floor; the upper story being divided into bedchambers for the family, with garrets over them for the servants. The kitchens should be placed upon arched cellars on several accounts, not the least of which is that the farmer should have the means of preserving in good condition the malt liquor or cyder which is the principal beverage of his establishment. It is a sad mistake on the part of landed proprietors, though common enough, to think that such buildings are not only below the care of an architect, but that he is too ignorant of the wants of the farmer to be competent to the task; if, however, he will reflect for a moment, he must admit that the artist who can make the most of a large plot of ground, with numberless requirements in the accommodation, is not less able to turn to the greatest advantage for the comfort of the occupier even a small farm-house.

3004. In the erection of a larger farm-house the choice of the site, as before, must depend on the nature of the ground and the situation of the farm. Health and convenience are the primary governing matters. It must never be placed where it cannot be well drained. It should be central to the land, and as near the road as the conditions will admit. For such a building the principal door may open into a moderately wide passage, having therein a staircase to the upper rooms. On the right of the passage a common kitchen may be provided for the family, and on the left a room somewhat larger, which in very small farm-houses used to be called the best kitchen, but which in this may be really the parlour, where the family may sit retired from the servants. Under these, cellars, as above mentioned, may be provided. On the ground floor we may now add a bakehouse and scullery to the pantry and dairy provided in the first scheme, as also closets and such conveniences for the housewife. The floor above may be extended over the additional rooms just mentioned, thus giving lodging room to a larger number of persons than to those contemplated in the first scheme. "In this manner," says Ware, in his *Complete Body of Architecture*, folio, London, 1756, "the young architect will very easily see how to enlarge or contract his plan for the building of farm-houses, according to the intended bigness." . . . "They all consist of the same number of rooms, and in general of the same number of offices; this is where the bare article of convenience for farming is concerned. Where the inhabitant is grown rich, and intends to live in another manner, he may add what he pleases, which the architect may adopt." . . . "It is then no longer to be considered a farm-house, but as the house of some person of fortune, who intends to live as those independent of business do, but withal to have some farming in his eye." When the farm-house comes to this extent it trenches hard upon the condition of the villa, though not quite reaching it, because the latter includes many provisions for a refined mode of living which the yeoman, the pride of England, does not require; a class which, we fear, the manufacturing and commercial classes are fast annihilating.

Sect. XXIV.

COTTAGES.

3005. "Estates," observes Kent, (*Hints to Gentlemen of Landed Property*, 8vo. London, 1776,) "being of no value without hands to cultivate them, the labourer is one of the most valuable members of society: without him the richest soil is not worth owning." It follows, then, that his condition should be most especially considered, and it is a duty on every country gentleman to take care that the labourers on his estate are so considered as to be made at least comfortable. "The shattered hovels," says the same author, "which half the poor of this kingdom are obliged to put up with, is truly affecting to a heart fraught with humanity." . . . "The weather penetrates all parts of them, which must occasion illness of various kinds, particularly agues; which more frequently visit the children of cottagers than any others, and early shake their constitutions." . . . "We are careful of our horses, nay, of our dogs, which are less valuable animals; we bestow considerable attention upon our stables and kennels, but we are apt to look upon cottages as incumbrances and clogs to our property, when, in fact, those who occupy them are the very nerves and sinews of agriculture." We fear the neglect of the comfort of the cottager has given a greater impulse to poaching and other crimes than his natural propensities have induced. This, however, is not a matter for discussion here. It is not to be supposed that we mean the labourer is to be placed in an expensive dwelling; a difference of rank must exist; and if the whole revenue of the country were divided among the population per head, it would be seen (as M. Dupin has recently shown in a most eloquent and sound address delivered in Paris as respects France) that the division of it per day, after allowing for the expenses of the most economical government that could be devised, would be such as would not satisfy the lowest class of labourer, much less the ingenious mechanic. This is a matter so susceptible of proof, and so proper to be generally promulgated, that we have here gone a little out of our way lest we should be considered too urgent with respect to the cottager.

3006. No cottage ought to be erected which does not contain a warm, comfortable, plain room, with an oven to bake the bread of its occupier; a small closet for the beer and provisions, two wholesome lodging rooms, one whereof should be for the man and his wife, and the other for his children. It would be well always, if possible, that the boys and girls in a cottage should be separated; but this unfortunately entails an expense, and perhaps is not so materially necessary, because the boys find employment at an early age. A shed for fuel should be attached.

Cottages should always be placed in sheltered spots, and as near as possible to the farm where the labourer is employed. The wear and tear of a man is not very dissimilar to that of an engine, and it tends as much to the interest of the farmer as it does to the comfort of the labourer that all unnecessary fatigue be avoided.

3007. In the erection of cottages it is not only more economical, but more comfortable to the occupiers, that they should be built double, or in twos at least. In those provinces where brick or stone can be obtained they should never be constructed with timber, and tiles, if they can conveniently be had, should always supersede thatch. Further observation on this subject will be unnecessary, for we have ill delivered the principles of our art if the student be not now prepared to carry out the few hints on the subject of cottages, — buildings, in point of fact, of importance paramount to the palace which the sovereign inhabits.

The following remarks are from a very talented and practical person, J. C. Loudon, Esquire.

"The *essential requisites* of a comfortable labourer's cottage may be thus summed up: —

"1. The cottage should be placed alongside a public road, as being more cheerful than a solitary situation, and in order that the cottager may enjoy the applause of the public when he has his garden in good order and keeping.

"2. The cottage should be so placed that the sun may shine on every side of it during the day throughout the year, when he is visible. For this reason, the front of the cottage can only be parallel to the public road in the case of roads in the direction of north-east, south-west, north-west, and south-east; in all other cases the front must be placed obliquely to the road, which, as we have previously shown, is greatly preferable to having the front parallel to the road.

"3. Every cottage ought to have the floor elevated, that it may be dry; the walls double or hollow, or battened, or not less than eighteen inches thick, that they may retain heat; with a course of slate or flagstone, or tiles bedded in cement, six inches above the surface, to prevent the rising of damp; the roof thick or double, for the sake of warmth; and projecting eighteen inches or two feet at the eaves, in order to keep the walls dry, and to check the radiation of heat from their exterior surface.

"4. In general, every cottage ought to be two stories high, so that the sleeping rooms may not be on the ground floor; and the ground floor ought to be from six inches to one foot above the outer surface.

"5. The minimum of accommodation ought to be the kitchen or living room, a back kitchen or wash-house, and a pantry, on the ground-floor, with three bedrooms over; or two rooms and a wash-house on the ground-floor, and two bedrooms over.

"6. Every cottage, including its garden, yard, &c., ought to occupy not less than one sixth of an acre; and the garden ought to surround the cottage, or at all events to extend both before and behind. In general, there ought to be a front garden and a back yard, the latter being entered from the back kitchen, and containing a privy, liquid manure tank, place for dust and ashes, and place for fuel.

"7. If practicable, every cottage ought to stand singly, and surrounded by its garden; or at all events not more than two cottages ought to be joined together. Among other important arguments in favour of this arrangement, it may be mentioned that it is the only one by which the sun can shine every day on every side of the cottage. When cottages are joined together in a row, unless that row is in a diagonal direction with reference to a south and north line, the sun will shine chiefly on one side. By having cottages singly or in pairs, they may always be placed along any road in such a manner that the sun may shine on every side of them, provided the point be given up of having the front parallel to the road, a point which in our opinion ought not for a moment to be put in competition with the advantages of an equal diffusion of sunshine.

"8. Every cottage ought to have an entrance porch for containing the labourer's tools, and into which, if possible, the stairs ought to open, in order that the bedrooms may be communicated with, without passing through the front or back kitchen. This, in the case of sickness, is very desirable, and also in the case of deaths, as the remains may be carried down stairs while the family are in the front room.

"9. The door to the front kitchen or best room should open from the porch, and not from the back kitchen, which, as it contains the cooking utensils and washing apparatus, can never be fit for being passed through by a stranger, or even the master of a family, where proper regard is had by the mistress to cleanliness and delicacy.

"10. When there is a supply of clear water from a spring adjoining the cottage, or from some other efficient source, then there ought to be a well or tank, partly under the floor of the back kitchen for drawing it up for use, as hereafter described in detail. The advantages of having the tank or well under the back kitchen are, that it will be secure from frost, and that the labour of carrying water will be avoided.

"11. The privy should always be separated from the dwelling, unless it is a proper water-closet, with a soil-pipe communicating with a distant liquid manure tank or cesspool. When detached, the privy should be over or adjoining a liquid manure tank, in which a straight tube from the bottom of the basin ought to terminate; by which means the soil basin may always be kept clean by pouring down the common slops of the house. No surface being left from which smell can arise, except that of the area of the pipe, the double flap, to be hereafter described, will prevent the escape of the evaporation from this small surface, and also ensure a dry and clean seat.

"12. The situation of the liquid manure tank should be as far as possible from that of the filtered water tank or clear water well. It should be covered by an air-tight cover of flagstone, and have a narrow well adjoining, into which the liquid should filter through a grating, so as to be pumped up or taken away without grosser impurities, and in this state applied to the soil about growing crops.

"13. In general, proprietors ought not to intrust the erection of labourers' cottages on their estate to the farmers, as it is chiefly owing to this practice that so many wretched hovels exist in the best-cultivated districts of Scotland and in Northumberland.

"14. No landed proprietor, as we think, ought to charge more for the land on which cottages are built than he would receive for it from a farmer if let as part of a farm; and no more rent ought to be charged for the cost of building the cottage and enclosing the garden than the same sum would yield if invested in land, or, at all events, not more than can be obtained by government securities.

"15. Most of these conditions are laid down on the supposition that the intended builder of the cottage is actuated more by feelings of human sympathy than by a desire to make money; and hence they are addressed to the wealthy, and especially to the proprietors of land and extensive manufactories or mines."

3008. The preceding observations of Mr. Loudon are extracted from a "Report to Her Majesty's principal Secretary of State, from the Poor Law Commissioners, on an Enquiry into the Sanitary Condition of the Labouring Population of Great Britain." 8vo. London, 1842. We regret that this Report was not published in time for us to notice one portion of it under its proper head, namely, that of sewers, a subject on which a very lengthened experience has enabled us to acquire some knowledge. The writer of the Report, who himself cannot be supposed at all qualified for such a task, has recommended forms for sewers which practice has proved to be exceedingly inconvenient; and has moreover given to a gentleman having, as he says, "the experience and qualifications of an engineer," the credit of having invented a method of flushing the sewers, and of carrying off all the refuse by water: a scheme so far from novel that we ourselves have used it on a very extensive scale for the last thirty-five years at least. We have thought it right here to notice this Report, which in many other particulars is ill and carelessly drawn up. It is much to be regretted that it was not committed to more competent hands; we mean such parts as relate to the sifting and arrangement of the evidence whereon it is founded. But this is the course of things in this country: a briefless barrister, without the least preparatory education for the task, delivers opinions *ex cathedrâ*, on which a scientific person would pause. "Thus fools rush in where angels, &c." — but the quotation is trite.

APPENDIX.

I. — LAWS RELATING TO BUILDING.

The earliest legislative enactment relative to the buildings of the metropolis was, we believe, in the reign of Henry VII.; but the first important statute regulating the thickness of walls, &c. was passed in the 19th Charles II., and became necessary in rebuilding the city after the great fire in 1666. This was, however, deemed insufficient, for the common council of the city of London found it necessary to pass, on the 29th of April, 1667, some resolutions for regulating buildings therein, which resolutions were confirmed and made binding in the city on the 8th of May following by the king in council. The regulations thus made, as they are no longer in force, it is unnecessary here to enumerate; suffice it to say, that alterations were required, and that, consequently, they were enlarged, amended, and more fully explained by acts passed 6 Anne, c. 31.; 7 Anne, c. 17.; 11 Geo. I. c. 28.; 33 Geo. II. c. 30.; 4 Geo. III. c. 14.; 6 Geo. III. c. 27.; 6 Geo. III. c. 37.; 12 Geo. III. c. 73.; and, lastly, 14 Geo. III. c. 78., which repealed all the former acts, and is now the statute to which all buildings to be erected within the bills of mortality must conform. It is usually called the Building Act, and is in so many respects a mass of absurdity that it ought long since to have been repealed. As, however, it remains on the Statute Book, this work would be incomplete without it; and it is therefore here printed at length, with some diagrams of illustration.

An Act for the further and better regulation of buildings and party-walls, and for the more effectually preventing mischiefs by fire, within the cities of London and Westminster and the liberties thereof, and other the parishes, precincts, and places within the weekly bills of mortality, the parishes of Saint Mary-le-bon, Paddington, Saint Pancras, and Saint Luke at Chelsea, in the county of Middlesex; and for indemnifying, under certain conditions, builders and other persons against the penalties to which they are or may be liable for erecting buildings within the limits aforesaid contrary to law.

12 G. III. c. 73.

Whereas an act of Parliament made and passed in the twelfth year of his present Majesty's reign, intituled "An Act for the better regulation of buildings and party-walls within the cities of London and Westminster and the liberties thereof, and other the parishes, precincts, and places in the weekly bills of mortality, the parishes of Saint Mary-le-bon and Paddington, Saint Pancras, and Saint Luke at Chelsea, in the county of Middlesex, and for the better preventing of mischiefs by fire within the said cities, liberties, parishes, precincts, and places; and for amending and reducing the laws relating thereto into one Act; and for other purposes," hath been found insufficient to answer the good purposes intended thereby: And whereas it may tend to the safety of the inhabitants, and prevent great inconveniences to builders and workmen employed in buildings within the said cities, liberties, parishes, precincts, and places, if the regulations contained in the said act were repealed, and other regulations and provisions respecting such buildings were established by law: May it please your Majesty that it may be enacted; and be it enacted by the king's most excellent Majesty, by and with the advice and consent of the lords spiritual and temporal, and commons, in this present parliament assembled, and by the authority of the same, that the several churches, chapels, meeting-houses, or other places of public worship, dwelling-houses, and all other buildings whatsoever, at any time heretofore begun or built, or which shall at any time or times hereafter be begun or built, within the said cities, liberties, parishes, precincts, and places, on new or old foundations, or on foundations partly new and partly old, shall be distinguished by and divided into the seven several rates or classes of building herein-after described; and such seven several rates or classes of building shall be under the rules and directions herein-after contained concerning the same.

Buildings divided into seven rates or classes.

First rate of building.

II. And be it further enacted, that every church, chapel, meeting-house, and other place of public worship, and every house or building for distilling and brewing of liquors for sale, for making of soap, for melting of tallow, for dyeing, for boiling or distilling turpentine, for casting brass or iron, for refining of sugar, for making of glass for chemical works for sale, of what dimensions soever the same respectively are or may be, and also every warehouse and other building whatsoever, not being a dwelling-house, now built or hereafter to be built, (except such buildings as are herein-after particularly declared to be of the fifth, sixth, or seventh rate or class of building,) which does or shall exceed three clear stories above ground, exclusive of the rooms (if any) in the roof thereof, or which is or shall be of the height of thirty-one feet from the surface of the pavement, ground, or way above the area before either of the fronts thereof, to the top of the blocking-course, or the coping on the parapet thereof, and every dwelling-house now built or hereafter to be built, which, with the offices thereto belonging and adjoining, or connected otherwise than by a fence or fence-wall, or covered passage open on one or both sides, when finished, does or shall exceed the value of eight hundred and fifty pounds, and also every dwelling-house which does or shall exceed nine squares of building on the ground-floor, each square containing one hundred superficial feet, shall be deemed the first rate or class of building.

Thickness of external walls to the first rate. Fig. 1034.

III. And it is hereby further enacted, that every front, side, end, or other external wall (not being a party-wall) which shall after the twenty-fourth day of June, in the year of our Lord one thousand seven hundred and seventy-four, be built to any first-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of two bricks and an half in length, or one foot nine inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall two inches and a quarter to the top of the footing of every such wall, except where any immediate adjoining building will not admit of such footing being made on the side of such wall next such adjoining building, in which case such footing shall be made as near to the dimensions herein directed as the case will admit; which footing shall be nine inches high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such wall shall, from the top of such footing, be of the thickness of two bricks in length, or one foot five inches and an half at the least, up to the under side of the one pair of stairs floor, and from thence of the thickness of one brick and an half in length, or thirteen inches at the least, up to the under side of the plate under the roof or gutter of every such building, and from thence of the thickness of one brick in length, or eight inches and an half at the least, up to the under side of the blocking-course or coping on the parapet of every such first-rate building, except such parts of every such wall as shall be wholly of stone, which parts so being of stone shall be of the thickness of fourteen inches at the least below the ground-floor, and of nine inches at the least above the ground-floor, and except all recesses above the ground-floor in the said walls, which shall be arched over in every story, so nevertheless as that the arch and the back of such recess shall be respectively of the thickness of one brick in length, or eight inches and an half at the least.

Thickness of party-walls to the first rate. See Fig. 1039.

IV. And it is hereby further enacted, that every party-wall which shall, after the said twenty-fourth day of June, be built to any first-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of three bricks and an half in length, or two feet six inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall four inches and an half to the top of the footing of every such wall, which footing shall be one foot high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such party-wall shall, from the top of such footing, be of the thickness of two bricks and an half in length, or one foot nine inches and an half at the least, up to the under side of the ground-floor, and from thence of the thickness of two bricks in length, or one foot five inches and an half at the least, up to the under side of the floor of the rooms (if any) in the roof of the highest building adjoining to such party-wall, and from thence of the thickness of one brick and an half in length, or thirteen inches at the least, up to the top of every such party wall.

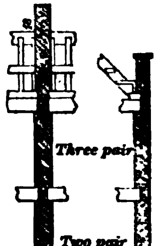

Fig. 1039.

Second rate.

V. And be it further enacted, that every warehouse, stable, and other building, not being a dwelling-house, except such buildings as are herein particularly declared to be of the first, fifth, sixth, or seventh rate or class of building, now built or hereafter to be built, which does or shall exceed two clear stories, and shall not contain more than three clear stories above ground, exclusive of the rooms (if any) in the roof thereof, or which is or shall be of the height of twenty-two feet and shall not be of the height of thirty-one feet from the surface of the pavement, ground, or way above the area before either of the fronts thereof to the top of the blocking-course or coping on the parapet thereof, and every dwelling-house now built or hereafter to be built which, with the offices thereto belonging and adjoining, or connected otherwise than by a fence or fence wall, or covered passage open on one or both sides, when finished, does or shall exceed the value of three hundred pounds, and shall not amount to more than the value of eight hundred and fifty pounds, and also every dwelling-house which does or shall exceed five squares of building on the ground plan, and shall not amount to more than nine squares of building on the ground plan thereof, shall be deemed the second rate or class of building.

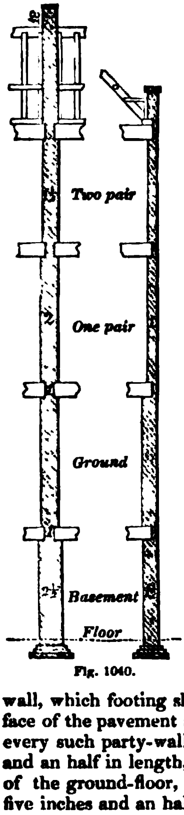

Fig. 1040.

VI. And it is hereby further enacted, that every front, side, or other external wall (not being a party-wall) which shall, after the said twenty-fourth day of June, be built to any second-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of two bricks in length, or one foot five inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall two inches and a quarter to the top of the footing of every such wall, except where any immediate adjoining building will not admit of such footing being made on the side of such wall next such adjoining building, in which case such footing shall be made as near to the dimensions herein directed as the case will admit, which footing shall be nine inches high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such wall shall, from the top of such footing, be of the thickness of one brick and an half in length, or thirteen inches at the least, up to the under side of the one pair of stairs floor, and from thence of the thickness of one brick in length, or eight inches and an half at the least, up to the under side of the blocking-course or the coping on the parapet of every such second-rate building, except such parts of every such wall, being above the ground-floor, as shall be wholly of stone, which parts so being of stone shall be of the thickness of nine inches at the least, and except all recesses above the ground-floor in the said walls, which shall be arched over, so nevertheless as that the arch and the back of each such recess shall respectively be of the thickness of one brick in length, or eight inches and an half at the least.

Thickness of external wall to the second rate. Fig. 1035.

VII. And it is hereby further enacted, that every party-wall which shall, after the said twenty-fourth day of June, be built to any second-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of three bricks and an half in length, or two feet six inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall four inches and an half to the top of the footing of every such wall, which footing shall be nine inches high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such party-wall shall, from the top of such footing, be of the thickness of two bricks and an half in length, or one foot nine inches and an half at the least, up to the under side of the ground-floor, and from thence of the thickness of two bricks in length, or one foot five inches and an half at the least, up to the under side of the floor of the two pair of stairs story, and from thence of the thickness of one brick and an half in length, or thirteen inches at the least, up to the top of every such party-wall.

Thickness of party-walls to the second rate. Fig. 1040.

VIII. And be it further enacted, that every warehouse, stable, and other building, not being a dwelling-house, except such buildings as are herein particularly declared to be of the first, fifth, sixth, or seventh rate or class of building, now built or hereafter to be built, which does or shall exceed one clear story and shall not contain more than two clear stories above ground, exclusive of the rooms (if any) in the roof thereof, or which is or shall be of the height of more than thirteen feet and shall not be of the height of twenty-two feet from the surface of the pavement, ground, or way above the area before either of the fronts thereof to the top of the blocking-course or the coping on the parapet thereof, and every dwelling-house now built or hereafter to be built which, with the offices thereto belonging and adjoining, or connected otherwise than by a fence or fence-wall, or covered passage open on one or both sides, when finished, does or shall exceed the value of one hundred and fifty pounds and shall not amount to more than the value of three hundred pounds, and also every dwelling-house which does or shall exceed three squares and an half of building on the ground plan and shall not amount to more

Third rate.

than five squares of building on the ground plan thereof, shall be deemed the third rate or class of building.

Thickness of external walls to the third rate. Fig. 1036.

IX. And it is hereby further enacted, that every front, side, end, or other external wall (not being a party-wall) which shall, after the said twenty-fourth day of June, be built to any third-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of two bricks in length, or one foot five inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall two inches and a quarter to the top of the footing of every such wall, except where any immediate adjoining building will not admit of such footing being made on the side of such wall next such adjoining building, in which case such footing shall be made as near to the dimensions herein directed as the case will admit, which footing shall be six inches high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such wall shall, from the top of such footing, be of the thickness of one brick and an half in length, or thirteen inches at the least, up to the under side of the ground-floor, and from thence of the thickness of one brick in length, or eight inches and an half at the least, up to the under side of the blocking-course or coping on the parapet of every such third-rate building.

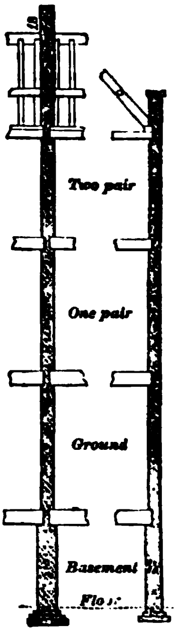

Fig. 1041.

Thickness of party-walls to the third rate. Fig. 1041.

X. And it is hereby further enacted, that every party-wall which shall, after the said twenty-fourth day of June, be built to any third-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of three bricks in length, or two feet two inches at the least, and shall from thence regularly and gradually diminish on each side of the wall four inches and an half to the top of the footing of every such wall, which footing shall be nine inches high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such party-wall shall, from the top of such footing, be of the thickness of two bricks in length, or one foot five inches and an half at the least, up to the under side of the ground floor, and from thence of the thickness of one brick and an half in length, or thirteen inches at the least, up to the top of every such party wall.

Fourth rate.

XI. And be it further enacted, that every warehouse, stable, and other building, not being a dwelling-house, except such buildings as are herein particularly declared to be of the first, fifth, sixth, or seventh rate or class of building, now built or hereafter to be built, which does not or shall not exceed one clear story above ground, exclusive of the rooms (if any) in the roof thereof, or which is not or shall not be of the height of more than thirteen feet from the surface of the pavement, ground, or way above the area before either of the fronts thereof to the top of the blocking-course or coping on the parapet thereof, and every dwelling-house now built or hereafter to be built, which, with the offices thereto belonging and adjoining, or connected otherwise than by a fence or fence-wall, or covered passage open on one or both sides, when finished, does not or shall not exceed the value of one hundred and fifty pounds, and also every dwelling-house which does not or shall not exceed three squares and an half of building on the ground plan thereof, shall be deemed to be of the fourth rate or class of building.

Thickness of external walls to the fourth rate. Fig. 1042.

XII. And it is herby further enacted, that every front, side, end, or other external wall which shall, after the said twenty-fourth day of June, be built to any fourth-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of two bricks in length, or one foot five inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall two inches and a quarter to the top of the footing of every such wall, except where any immediate adjoining building will not admit of such footing being made on the side of such wall next such adjoining building, in which case such footing shall be made as near to the dimensions herein directed as the case will admit, which footing shall be six inches high at the least, and wholly below the

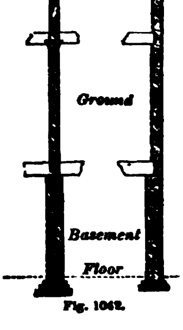

Fig. 1042.

upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such wall shall, from the top of such footing, be of the thickness of one brick and an half in length, or thirteen inches at the least, up to the under side of the ground-floor, and from thence of the thickness of one brick in length, or eight inches and an half at the least, up to the under side of the blocking-course or coping on the parapet of every such fourth-rate building.

Thickness of party-walls to the fourth rate. Fig. 1037.

XIII. And it is hereby further enacted, that every party-wall which shall, after the said twenty-fourth day of June, be built to any fourth-rate building, or to any addition thereto or enlargement thereof, shall be built and remain, at the foundation thereof, of the thickness of two bricks in length, or one foot five inches and an half at the least, and shall from thence regularly and gradually diminish on each side of the wall two inches and a quarter to the top of the footing of every such wall, which footing shall be nine inches high at the least, and wholly below the upper surface of the pavement and flooring-boards of the cellar story two inches at the least; and every such party-wall shall, from the top of such footing, be of the thickness of one brick and an half in length, or thirteen inches at the least, up to the under side of the ground-floor, and from thence of the thickness of one brick in length, or eight inches and half at the least, up to the top of every such party-wall.

Party-walls to be between house and house and other buildings, except in such parts where each have independent walls.

XIV. And it is hereby enacted by the authority aforesaid, that from and after the said twenty-fourth day of June every house or building thereafter to be built, and being of the first, second, third, or fourth rate or class of building herein-before directed, and not having each of them a separate and distinct side-wall on the part or parts where they are or shall be contiguous, shall have party-walls between house and house or other buildings, or between so much of such house and house or other buildings as shall not respectively have such separate and distinct walls as aforesaid; and such party-walls shall extend to the outer surfaces of the external inclosures of each of the adjoining houses or buildings; and all party-walls, and also all chimneys and chimney-shafts hereafter to be built, shall be built wholly of good sound bricks or stone, or of good sound brick and stone together, except such timber, wood, lead, or iron work as shall or may be laid therein according to the directions herein-after contained, and also except such piling, bridging, or planking as may be necessary for the foundation thereof; and every such party-wall shall be topped or coped with stone, tile, or brick, and shall be of the dimensions herein-before directed; and one half of every such party-wall between house and house, or between other buildings, shall be built on the ground or scite of one of the adjoining houses or buildings, and the other half thereof shall be built on the ground or scite of the other of the adjoining houses or buildings; and it shall be lawful for the first builder of any such party-wall, and for the workmen employed in building the same, to enter upon the ground adjoining thereto in order to the building such party-wall in manner aforesaid.

All party-walls above four stories high to be built as of the first rate.

Party-walls to fourth-rate houses, being four stories high, to be built as of the third rate.

XV. Provided nevertheless, and it is hereby enacted, that every party-wall which shall, after the said twenty-fourth day of June, be built to any dwelling-house exceeding four stories in height from the foundation thereof, exclusive of the rooms (if any) in the roof of either of the buildings adjoining thereto, shall be built in every particular according to the directions herein-before contained with respect to the party-walls of the first rate or class of building, notwithstanding such house shall not be of the first rate or class of building; and every party-wall which shall, after the time aforesaid, be built to any dwelling-house containing four stories in height from the foundation thereof, exclusive of the rooms (if any) in the roof of either of the buildings adjoining thereto, shall be built in every particular according to the directions herein-before contained with respect to party-walls of the third rate or class of building, notwithstanding such house shall be of the fourth rate or class of building only.

Materials of divisions of different possessions in the first, second, third, and fourth rates.

XVI. And it is hereby further enacted, that every internal inclosure to be made after the said twenty-fourth day of June for separating any building of the first, second, third, or fourth rate or class of building from any other building, where such buildings shall be in separate occupations, and every addition or enlargement to such internal inclosure, shall be of brick or stone, or artificial stone or stucco, or of brick and stone or artificial stone or stucco together, except such timber, wood, lead, or iron work as may be laid therein according to the directions herein-after contained for external inclosures to such first, second, third, or fourth rate or class of building, and also except such piling, bridging, or planking as may be necessary for the foundation of the same.

Method of ascertaining the rate.

XVII. And it is hereby enacted by the authority aforesaid, that in valuing the several buildings herein before declared to be of the first, second, third, or fourth rate or class of building for the purpose of ascertaining the rate thereof, such valuation to be made by the surveyor or surveyors to be appointed pursuant to this act for the district in which the building is or may be situated by as true a measure and estimation as the nature of the case will admit; and every such building shall, notwithstanding any decay therein, be estimated and valued as if the materials whereof the same consists were sound and the work thereof new; and every such building shall be estimated and valued at the several prices the like materials and workmanship shall be worth at the time such valuation shall be made; but neither the soil whereon any such building stands, nor any fence or fence-wall, (except the railing to areas, and steps before or behind such building, made for the purpose of inclosing the said building, with the offices, yard, or appurtenances thereto belonging, from any neighbouring ground,) nor any brick or stone arched vault or vaults under the surface of the ground, either before or behind such building, nor any lead, covering, or pavements over such vaults, nor such parts of the party-wall or party-walls to such building as stand upon ground not belonging to such house, shall be included in any such valuation; and in ascertaining the squares of building contained in every such building, being a dwelling-house, the same shall be taken by the surveyor or surveyors as aforesaid on the level of the floor at the principal entrance to such dwelling-house, and no more than such parts of the party-walls as belong to such dwelling-house shall be included in such admeasurement; and in case the owner or any other person interested in such building shall apprehend him or herself to be injured by the admeasurement or valuation made by such surveyor or surveyors as aforesaid, it shall be lawful for such owner or other person to apply to the mayor or any two justices of the peace for the city of London, if such building or any part thereof is situated within the said city, or otherwise to any two justices within whose jurisdiction the same is situated, and the said mayor or justices shall inquire into the matter, and shall, by his or their order, declare such building to be of such rate or class as the same shall to him or them appear to be of, according to the description of the several rates or classes herein-before contained; and it shall be lawful for any of the parties between whom such order shall be made to appeal to the justices of the peace at their general quarter sessions of the peace, whose order and determination shall be binding and conclusive to all parties.

Squares taken at the level of the entrance.

Fifth rate of building.

XVIII. And be it further enacted, that every dwelling-house, warehouse, stable, and other building, (except such buildings, not being dwelling-houses, as are herein-before particularly declared to be of the first or seventh rate or class of building,) which is or shall be at the distance of four feet and not eight feet from any public road, street, or causeway, and is or shall be detached from any other building not in the same possession therewith sixteen feet at the least and not thirty feet, or connected with any other building only by a fence or fence-wall, shall be deemed to be of the fifth rate or class of building, and shall and may be built of any dimensions whatever.

Sixth rate of building.

XIX. And be it further enacted, that every dwelling-house, warehouse, stable, and other building, (except such buildings, not being dwelling-houses, as are herein-before particularly declared to be of the first rate or class of building,) which is or shall be at the distance of eight feet from any public road, street, or causeway, and is or shall be detached from any other building not in the same possession therewith at least thirty feet, or connected with any other building only by a fence or fence-wall, shall be deemed to be of the sixth rate or class of building, and shall and may be built of any dimensions and with any materials whatever.

Seventh rate of building.

XX. And be it further enacted, that every cranehouse now built or hereafter to be built on any wharf or quay, and every shamble, windmill, or watermill, and also every building which is or shall be situated without the cities of London and Westminster, and the liberties thereof, used for workshops or drying places for tanners, fellmongers, glue-makers, size-makers, calico-printers, whitsters, whiting-makers, curriers, leather-dressers, buckram-stiffners, oil-cloth painters, wool-staplers, throwsters, parchment-makers, and paper-makers, so long and at such times as they are or shall be used for some or one of those purposes, and no longer, shall be deemed the seventh rate or class of building, and may be built of any dimensions whatever.

Materials of Cranehouses.

XXI. And it is hereby further enacted, that every such cranehouse which shall be erected and built after the said twenty-fourth day of June, and every addition or enlargement to any cranehouse already built or hereafter to be built, and every new side, new end, or other new external inclosure which shall, after the said twenty-fourth day of June, be made to any such cranehouse, or to any addition or enlargement thereof, shall be of stone, brick, slate, tile, oak, elm, steel, iron, or brass; but every other building of the seventh rate or class of building may be erected of any materials whatever; and no cranehouse or other building of the seventh rate or class of building, or any external part thereof, shall, after the said twenty-fourth day of June, be covered with pitch, tar, or any other inflammable composition or material whatever, nor shall, after the said twenty-fourth day of June, be converted to any other use than as aforesaid.

No seventh rate building to be covered with pitch, tar, &c.

Detached offices deemed of the same rate as if

XXII. And in order to prevent doubts which may arise concerning the rate or class of building of any office or offices now built or hereafter to be built, belonging to any building herein-before declared to be of the first, second, third, or fourth rate or class of building, it is hereby further enacted and declared, that every such office which shall be entirely free and detached from such building to which the same belongs, or shall be connected therewith only by a fence or fence-wall, or covered passage open on one or both sides, shall be deemed to be of the rate or class of building such office would be of if the same did not appertain to any dwelling-house or other building.

Independent of any other building.

XXIII. And whereas some houses or other buildings erected or begun to be erected before the said twenty-fourth day of June may have one or more good sound party-wall or party-walls, although not built agreeable to the several rules herein-before directed to be observed concerning party-walls to be built after the said twenty-fourth day of June, and in such case it may happen that one of the adjoining houses may have been or may hereafter be rebuilt, without making use of such party-wall or party-walls; it is therefore hereby enacted, that every such wall may remain as a party-wall until both the houses or buildings to which the same belongs, or the remaining house or building where one has been already rebuilt, shall be rebuilt, (if such wall shall so long continue sound,) and no longer; and that in case either of the houses or buildings to which any such party-wall does belong has been or shall hereafter be rebuilt with a wall against such party-wall (without making use of such party-wall) of the heights and thicknesses herein-before prescribed for side-walls, the proprietor of such remaining house or building shall not, when such remaining house or building or when such old party-wall shall be taken down, be entitled to more than one half of the materials of such old party-wall, nor to more than one half of the ground on which such old party-wall was erected; nor shall such proprietor build on more than one half of the said ground, unless he shall have agreed with and satisfied the owner or owners of such adjoining rebuilt house for the other half thereof; and in case the parties cannot agree concerning the same, and both or either of them shall be desirous of buying or selling, the price and the matters in difference shall be settled by a jury to be summoned, returned, and impannelled as herein-after is mentioned concerning mixed property; but if such remaining house or building be of the first, second, or third rate or class of building, or be four stories high from the foundation thereof, exclusive of the rooms (if any) in the roof thereof, and if in that case such old party-wall shall not be of the thickness of two bricks in length, or one foot five inches and an half at the least, from the foundation thereof to the under side of the ground floor, and from thence upwards to the top thereof of the thickness of one brick and an half in length, or thirteen inches at the least, then such old party-wall shall, when either of the houses or buildings to which the same belongs shall be rebuilt, be considered as if the same had been condemned or adjudged ruinous pursuant to the directions herein-after contained for condemning or adjudging ruinous any unsound party-wall; or if such old party-wall shall have any timber or timbers of any adjoining building lying through the same, and if when either of the houses or buildings to which the same belongs shall be rebuilt the owner or owners of such adjoining or remaining house or building will not permit so much of such timber to be cut off as shall leave full six inches of clear brickwork beyond the end of every such timber, then every such wall shall be considered as if the same had been condemned or adjudged ruinous pursuant to this act, and the same shall be taken down and rebuilt in such manner as is herein-after directed concerning party-walls which shall be so condemned or adjudged ruinous.

How long old sound party-walls may remain.

Where one adjoining built with independent walls, the owner of the other to have but half the materials and half the scite o the old party-wall when pulled down.

Party-walls not being of sufficient thickness to be taken down, when one of the houses is rebuilt.

Ends of timbers lying through old party-walls to be cut off when one building is rebuilt.

XXIV. And whereas some houses or other buildings erected or begun to be erected before the said twenty-fourth day of June one thousand seven hundred and seventy-four may have one or more good and sound timber partition or timber partitions between the same and the adjoining house or building; it is hereby enacted, that every such timber partition may remain until one of the adjoining houses or buildings to which the same belongs shall be rebuilt, or shall have one of the fronts which shall abut on such timber partition, or two third parts of one of such fronts, taken down to the bressummer or one pair of stairs floor, and rebuilt, or until such timber partition shall be condemned pursuant to the directions herein-after contained concerning ruinous or defective party-walls and party-partitions, and no longer.

Timber partitions to be taken down when one house or one front is rebuilt.

XXV. And, as a further security against fire, it is hereby enacted, that no wall or walls of any building of the first, second, third, or fourth rate or class of building, already erected or built or hereafter to be erected or built, or of any addition or enlargement made or to be made to any building of such first, second, third, or fourth rate or class of building, which shall not be a party-wall on the said twenty-fourth day of June, shall ever be or become a party-wall, unless the same shall be and remain of the heights and thicknesses above the footings, and of the materials, herein-before directed concerning party-walls to be erected after the time aforesaid.

External walls shall not become party-wall.

XXVI. And, as a greater security from fire, it is hereby further enacted, that every

Party-walls to be one foot six inches above any building which shall gable against them.

What recesses may be in party-walls.

What openings may be in party-walls.

party-wall which shall be built after the said twenty-fourth day of June, and every addition or enlargement which shall be thereafter made to any party-wall then built or thereafter to be built, shall be carried up and remain one foot six inches at the least above the roof of the highest building which shall gable against or adjoin to such party-wall in every part of such party-wall where such building shall gable or adjoin thereto, measuring at a right angle with the back of the rafters of such roof; and every such party-wall shall be carried up and remain one foot at the least above the gutters of the highest of such buildings, except the height of such party-wall, where so carried up, shall exceed the height of the blocking-course or parapet of either of the fronts abutting on the same of the highest building adjoining thereto, in which case the end only of every such party-wall next such blocking-course or parapet may be less than one foot above the gutter for the distance of two feet six inches from the front of such blocking-course or parapet; and in case any dormer or other erection is or shall be fixed in the flat or roof of any building within four feet of any party-wall, then every such party-wall shall be carried up against every such dormer or other erection, and shall extend for the breadth of at least two feet wider, and to the full height of every part of every such dormer or other erection as shall be within four feet of such party-wall; and no recess shall be made in any party-wall hereafter to be built to any building of the first, second, third, or fourth rate or class of building, (except for chimneys, flues, girders, and beams, and other timbers, and for the ends of walls or piers, as herein-after is directed,) so as to reduce such wall in any part thereof under the thickness by this act required for the party-wall to the highest rate or class of building to which such party-wall belongs; and there shall not be any opening whatever, after the said twenty-fourth day of June, made in any party-wall, except for communication from one stack of warehouses to another, and from one stable building to another, all which communications shall have thereto iron doors in such manner as is herein-after directed, and also except such passages or ways on the ground for foot passengers, cattle, or carriages as may be necessary, all which passages or ways shall be arched over with brick or stone, or brick and stone together, throughout, of the thickness of thirteen inches at the least in every building of the first and second rate or class of building, and of the thickness of eight inches and an half at the least in every building of the third or fourth rate or class of building; and if there be any cellar or vacuity under any such passage, every such cellar or vacuity shall be arched over throughout with brick or stone, or brick and stone together, in the same manner as the passage or way over such cellar or vacuity is hereby directed to be arched.

How ends of beams may be laid into party-walls.

XXVII. And it is hereby further enacted, that no timbers shall, at any time after the said twenty-fourth day of June, be laid into any party-arch, except for bond to the same, nor into any party-wall, other than such templets, chains, and bond-timbers as shall be necessary for the same, and other than the ends of girders, beams, purlings, and of binding or trimming joists, or of other principal timbers, all which timbers shall have at least eight inches and an half of solid brickwork between the ends and sides of every such piece of timber and the timber of any building adjoining thereto; and the end of every girder, beam, purling, binding or trimming joist, and of every other piece of principal timber, may be laid beyond the centre of any party-wall hereafter to be built, so nevertheless as that there be left eight inches and an half at the least of solid brick or stone work at the end of every such piece of timber, except in places where any part of the ends of any such timber shall lie opposite to and level with any part of the ends of any timber of any adjoining building or buildings, in which case no part of such timbers shall approach nearer than four inches to the centre of the said wall.

Party-arches and party-walls not to be maimed.

For what uses party-walls may be cut into.

XXVIII. And it is hereby further enacted, that no person shall cut or maim any party-arch, nor the shaft of any chimney now built or hereafter to be built on any party-wall, for any purpose whatsoever; and that no person shall cut or maim any party-wall now built or hereafter to be built, other than for the purposes and in the manner herein-after mentioned; that is to say, when the front or back wall of any house or building, being in a line with the front or back wall of the house or building adjoining thereto, shall at any time hereafter be built, it shall be lawful to cut a break not more than nine inches deep from the external face of such front or back wall, and to the centre of such party-wall, for the purpose of inserting therein the end of such new front or back wall; and in every such case where a bressummer and story-post shall be fixed in the ground story of such new front or back wall, such break may be cut from the foundation of such new front or back wall to the top of such bressummer fourteen inches deep from the external face of such front or back wall, and the same may be four inches wide in the cellar story, and two inches wide in the ground story, for the purpose of placing therein such story-posts and bressummers agreeable to the directions of this act; and it shall be lawful to cut into any party-wall for the purpose of tailing in stone steps or stone landings, or for placing in such party-wall timber for bearers to wood stairs, so as no timber bearer be laid into any party wall nearer than eight inches and an half to any chimney or flue whatever, or to any timber of the adjoining house or building, or nearer than four inches to the internal finishing of such adjoining house or building, and for the purpose of laying therein stone corbels for the support of chimney-jambs, girders, beams, purlings, binding or trimming joists, or of other principal timbers; and it shall also be lawful to cut perpendicular recesses into any party-wall not being less than thirteen inches thick, for the purpose of inserting walls and piers therein, so nevertheless as that no such recess be more than fifteen inches wide, or more than four inches deep, and that no such recess be nearer than ten feet to any other recess; and that it shall be lawful to cut off the footing on the side of any party-wall where either of the adjoining buildings shall be rebuilt with a wall against such party-wall; but every person who shall cut into any party-wall for any of the purposes aforesaid shall immediately make good, and well and effectually pin up with brick, stone, slate, tile, shell, or iron, bedded in mortar, every defect which shall be occasioned by the cutting of any such party-wall; and no party-wall shall be cut for any of the purposes aforesaid if the cutting thereof will injure, displace, or endanger the timbers, chimneys, flues, or internal finishings of the adjoining buildings.

Thickness of backs of chimneys in party-walls.

How chimneys may be built back to back in party-walls.

How flues may be built back to back in party-walls.

Thickness of breasts of flues; and withs.

Chimneys to be pargetted.

XXIX. And it is hereby further enacted, that the back of every chimney in every party-wall which shall, after the said twenty-fourth day of June, be built, shall be at least thirteen inches thick in the cellar story, and eight inches and an half thick in every other story, from the hearth of every such chimney to the height of twelve inches above the mantel in every such chimney; and that no chimney which shall, after the said twenty-fourth day of June, be built in any party-wall where either of the buildings adjoining thereto is of the first rate or class of buildings, shall be built with the back thereof against the back of any other chimney, unless the back of each chimney in the cellar story be at least eight inches and an half, and the back of each chimney in any of the upper stories be at least four inches and a quarter, from the centre of such party-wall; and that no chimney which shall, after the said twenty-fourth day of June, be built in any party-wall where either of the buildings adjoining thereto is of the second, third, or fourth rate or class of building, shall be built with the back thereof against the back of any other chimney, unless the back of each chimney in the cellar story be at least six inches and an half, and the back of each chimney in any of the upper stories be at least four inches and a quarter, from the centre of such wall; and that no flue shall be built opposite to another flue in any party-wall, unless the back of each flue be at least two inches from the centre of such party-wall; the breast of every flue which shall, after the said twenty-fourth day of June, be built, whether such flue be in a party-wall or not, shall be of brick or stone at least eight inches and an half thick in every cellar story, and at least four inches thick in every other story; all the withs or partitions between any flues which shall, after the said twenty-fourth day of June, be built, shall be of brick or stone, and every such with or partition of brick shall be at least half a brick thick; and every breast and back of every chimney, and every breast, back, and with, or partition of any flue, hereafter to be built, shall be rendered or pargetted within and without, except the outside thereof which shall be next to vacant ground, in which case the back of every chimney and flue next such vacant ground shall be by lime, or in some durable manner, marked and distinguished, except in a fore-front, back-front, or side-front of any building not likely hereafter to be built against; and every back of every such chimney and flue so being against such vacant ground shall be rendered or pargetted as soon as any building shall be erected to such wall.

Chimney-jambs, breasts, &c. to be placed in party-walls where desired by owner of adjoining ground.

XXX. Provided always, and be it enacted by the authority aforesaid, that if any person or persons, being possessed of or entitled unto any part of the ground whereon a party-wall is intended to be built, shall be desirous of having chimney-jambs, breasts, and flues of chimneys made in any such party-wall on his, her, or their part thereof, or shall be desirous of having a recess or recesses left in the said party-wall, of the several breadths and depths in and by this act allowed to be left or cut into any party-wall, for the purpose of inserting therein external or internal walls or piers, or for any other purpose allowed by this act, and of such desire shall give notice in writing under his, her, or their hands, particularly describing every such chimney-jamb, breast, and flue, and every such recess, to the builder or builders of such party-wall, or any one of them, at any time before such party-wall shall be begun to be built, then such builder or builders of such party-wall shall, after such notice so given, erect in a proper, substantial, and workmanlike manner such and so many chimney-jambs, breasts, and flues of chimneys in all such parts of every such party-wall as shall be by the person or persons giving such notice required, and shall also leave such recesses in every such party-wall, not being in any respect contrary to the rules, regulations, and restrictions in and by this act prescribed; and from and after the erecting such jambs, breasts, and flues of chimneys so required the person or persons giving such notice, his, her, or their executors and administrators, shall be deemed to have made use of such party-wall, and shall from thenceforth be liable to pay the whole expense of erecting and setting up all such jambs, breasts, and flues of chimneys erected in pursuance of such notice, and also such proportional part of the expense of erecting such wall as is herein-after directed concerning party-walls to be built after the said twenty-fourth day of June, to be recovered, in case of nonpayment, with full costs of suit, in like manner as any proportion of any party-wall is by this act made recoverable by the builder thereof from any other person liable to contribute thereto.

Regulation of party-walls, &c. between intermixed property.

XXXI. And whereas several houses and other buildings within the limits aforesaid are built in some part thereof over a public way, and in several houses or other buildings within the limits aforesaid several of the rooms or floors of such houses or buildings are the property of different owners, and lie intermixed, without being separated by any party-wall, and without being arched over and under each other with brick or stone, or brick and stone, throughout; be it therefore enacted, that when any house or other building, except as herein-after is excepted, so built, in any part thereof, over a public way, or any house or building, except as herein-after is excepted, having any rooms the property of different persons and intermixed as aforesaid, shall be rebuilt, there shall be a party-wall according to the directions herein-before contained for the highest rate or class of building adjoining thereto, with a party-arch or party-arches of the thickness of one brick and an half in length, or thirteen inches at the least, in every building of the first and second rate or class of building, and of the thickness of one brick in length, or eight inches and an half at the least, in every building of the third and fourth rate or class of building, between house and house or other building, or between the different rooms or floors so being the property of different persons as aforesaid.

Party-walls not to extend to inns of court, &c.

XXXII. Provided nevertheless, that the last-mentioned clause or provision relating to houses and buildings in part over public ways, or having the rooms or floors the property of different persons, shall not extend to all or any of the rooms or chambers in Serjeants' Inn in Chancery Lane, or in any of the four inns of court, or to any of the inns of chancery, or any other inns set apart for the study or practice of the law, save and except that the walls or divisions between the several rooms and chambers in such inns, belonging to and communicating with each separate and distinct staircase, shall be deemed and taken to be party-walls within this act, and shall be subject to all and every the regulations and clauses herein contained relating to other party-walls within the limits aforesaid.

Owners may be compelled to join in building party-walls, &c.

XXXIII. And whereas it may sometimes happen that no party-wall or party-arch can be built upon proper foundations between such houses and other buildings over public ways, or having rooms or floors the property of different persons, lying intermixed as aforesaid, without pulling down such houses or buildings, and laying parts of each to the others of such houses or buildings, and it may happen that the parties interested therein, or some or one of them, will not, or cannot by reason of some legal disability or otherwise, join in building such party-wall or party-arches as aforesaid, or in pulling down such houses, and laying parts of each to the other or others of such houses, in all which cases differences may arise among the said several owners, and the rebuilding the same, and the said party-walls or party-arches thereof, may be thereby prevented or delayed, to the great injury or inconvenience of such of the owners as are desirous of rebuilding; for remedy thereof, and in order to prevent the fatal effects of fire, be it enacted by the authority aforesaid, that in all and every or any of such cases, when any owner or owners of any such house or other building within the limits aforesaid, built over any public way or intermixed as aforesaid, shall be desirous of rebuilding such house or other building, and the owner or owners of the adjoining house or building, or of the other parts of such intermixed house or building, shall not be willing, or shall not by reason of some legal disability or otherwise be able, to join in such rebuilding, then the party or parties so desirous of rebuilding shall give notice in writing to the owner or owners of such adjoining house or houses or other buildings, or of the other parts of such intermixed house or building, that he, she, or they so intending to rebuild will apply to the court of mayor and aldermen of the city of London when such house or other building, or any part thereof, is situated within the said city or the liberties thereof, or to the justices of the peace for the county of Middlesex, or for the county of Surrey, or for the city and liberty of Westminster, or for the liberty of the Tower of London respectively, within whose jurisdiction such house or other building, or any part thereof, is situated, in their respective general or quarter sessions of the peace to be next holden after fourteen days from the delivery of such notice, in order to obtain the judgment and determination of the said court of mayor and aldermen, or of the said court of sessions, (as the case may be,) touching the rebuilding such house or houses or other buildings, or such party-walls or party-arches, to be described in such notice, and for ascertaining the scite of a party-wall or party-walls, or the situation of any party-arches, to be built according to the directions and restrictions in this act contained, by delivering a true copy of such notice to the owner or owners of such adjoining house or houses or other buildings, or of the other parts of such

Where owners are under disabilities, or houses are uninhabited, how differences are to be settled respecting the building of party-walls.

intermixed house or building; or in case such owner or owners shall be under the disability of coverture, infancy, idiotcy, or lunacy, then to the husband or husbands of such owner or owners under coverture, or to the guardians, trustees, or committees of such owners being under the disability of infancy, idiotcy, or lunacy respectively, or by leaving the same at his, her, or their last or usual place of abode, or by delivering a true copy of such notice to the tenant in possession of such adjoining house or houses or other buildings, or of the other parts of such intermixed house or building, or in case such house or building shall be uninhabited, then by fixing such copy, wrote fair and in a legible hand, to or upon the door or some other notorious part of such adjoining or intermixed house or other building which shall be uninhabited; and in every such case it shall and may be lawful to and for the said court of mayor and aldermen, and to and for the said court of sessions respectively, (as the case may be,) and they are hereby respectively authorised and required, upon application to them by the party or parties so desirous to rebuild, and upon such proof of such notice as they shall deem reasonable, to issue their warrant or warrants, precept or precepts, to the sheriffs of London, or to the sheriff of the said county of Middlesex, or sheriff of the said county of Surrey, or sheriff or bailiff of the liberty of His Majesty's Tower of London, (as the case may be,) requiring them or him respectively to impannel and return a competent number of substantial and disinterested persons qualified to serve on juries within the respective distances to which they are summoned, not less than twenty-four nor more than thirty-six; and out of such persons so to be impannelled, summoned, and returned, a jury of twelve persons shall be drawn by some person by the said court of mayor and aldermen or court of sessions respectively appointed in such manner as juries are directed to be drawn for the trial of issues joined in His Majesty's courts of record at Westminster by an act made in the third year of the reign of His late Majesty King George the Second, intituled "An Act for the better regulation of juries;" which persons so to be impannelled, summoned, and returned are hereby required to come and appear before the said court of mayor and aldermen, or before the said court of sessions for the said county of Middlesex, or county of Surrey, or city and liberty of Westminster, or the liberty of His Majesty's Tower of London (as the case may be), at such time and place as in such warrant or warrants, precept or precepts, shall be appointed, and there to attend from day to day until discharged by the court; and all parties concerned shall and may have their lawful challenges against any of the said jury, but shall not be at liberty to challenge the array; and the said court of mayor and aldermen, and any of the said courts of sessions for the said county of Middlesex or Surrey, or city and liberty of Westminster, or liberty of the Tower of London, is and are hereby authorised and empowered by precept or precepts, from time to time as occasion may require, to call before them respectively all and every person and persons who shall be thought proper or necessary to be examined as a witness or witnesses before them, on oath, concerning the premises; and either of the said courts, if they think fit, shall and may likewise authorise the said jury to view the place or places in question, in such manner as they shall direct, and shall have power to command such jury, and all such witnesses and parties as shall be necessary or proper, to attend until all such affairs for which they are summoned shall be concluded; and the said jury, upon their oaths, (which oaths, as also the oaths to persons called upon to give evidence, the said courts are hereby respectively empowered and required to administer,) shall inquire and try and determine by their verdict whether the premises in any of the cases aforesaid ought to be rebuilt or not, and if the same ought to be rebuilt shall award and determine the scite of a party-wall or party-walls, and also what party-arches may be necessary over or under any rooms of such house or houses or other buildings so intended to be rebuilt, or shall ascertain the quantity of the soil or ground or other parts of the premises (if any) necessary to be laid to or taken from the house of the person or persons desirous to rebuild, permitting such person or persons to erect a party-wall or party-walls, party-arch or party-arches, and shall ascertain and award what (if any) compensation should be made and paid by either or any of the said parties in difference to the other or others of them in lieu of the lessening either of the said houses or other buildings by such party-wall or party-walls, party-arch or party-arches, or as a satisfaction for such other injury (if any) as shall be done or occasioned thereby to any or either of the said parties, and shall also ascertain and award what proportion of the expense of building such party-wall or party-walls, party-arch or party-arches, shall, when the same are so built, be repaid by either or any of the parties in difference to the person or persons so rebuilding as aforesaid; and the said court of mayor and aldermen and the said court of sessions respectively shall give judgment according to such verdict, as well for determining the scite of such intended party-wall or party-walls, party-arch or party-arches, as also for such sum or sums of money (if any) so assessed by the said jury, and likewise for such proportion of the expense of building such party-wall or party-walls, party-arch or party-arches, so found or awarded by the said jury, to be repaid to the person or persons

3 G. II. c. 25.

Jury to determine what proportion of expense shall be paid by the owners of the adjoining premises.

Court to give judgment according to verdict;

and judgment to be binding.

Verdict, &c. to be recorded by town clerk or clerk of the peace.

Within fourteen days after judgment, and payment or tender of the money awarded, the owner of the intermixed house may pull it down, and also may enter the adjoining building in the presence of a peace officer;

and may remove goods and furniture.

Persons hindering the workmen, or damaging the work, to forfeit 10l.

who shall rebuild or shall have rebuilt the same, and shall and may (if they see fit) award to either of the parties such costs as they shall deem reasonable; which verdict or verdicts, and the judgment, order, or determination thereupon, shall be binding and conclusive against all and every person and perons, bodies politic and corporate, claiming any estate, right, title, trust, use, or interest in, to, or out of the said premises or any part thereof, either in possession, reversion, remainder, or expectancy, as also against the king's most excellent Majesty, his heirs and successors, and against infants and issue unborn, persons in reversion or remainder, lunatics, idiots, and femes covert, and persons under any other legal incapacity or disability, and against all trustees and cestuique trusts, his, her, and their successors, heirs, executors, and administrators, and against all other persons whomsoever; and all and every the said verdicts, judgments, orders, and determinations, and all other proceedings of the said court of mayor and aldermen, and court of sessions, so to be made, given, and pronounced as aforesaid, shall be, by the town clerk of the city of London, or by the clerk of the peace for the said county of Middlesex or Surrey or the city and liberty of Westminster, or the proper officer of the liberty of the said Tower of London, (as the case may be,) entered and filed as of record of the said court where such proceedings shall have been had, (for the entry and filing whereof, and for every order of court and copy thereof, the said town clerk or clerk of the peace, or other proper officer, shall be paid after the rate of twelve-pence for every one hundred words, and no more;) and each of them the said town clerk and clerk of the peace, or other proper officer respectively, is hereby empowered and required to make and deliver to any person requiring the same an exemplification under his hand and seal of any such verdict, judgment, order, and determination, being paid for the same after the rate of twelve-pence for every one hundred words, and every such exemplification shall and may be taken and read as evidence in all courts of law and equity whatever; and after the expiration of fourteen days from and after the obtaining such judgment, and payment or tender, in manner herein-after directed, of the sum or sums of money (if any) thereby assessed or awarded, or, where no sum of money shall be so assessed or awarded, after the expiration of fourteen days from and after the obtaining such judgment, the person or persons who shall have applied for and obtained such judgment, his, her, or their heirs, executors, or administrators, servants or workmen, shall and may pull down his, her, or their own house or other building, and rebuild the same in the manner so ascertained by such judgment, and to that end shall and may, in the presence of a constable or headborough, or other officer of the peace, after the end of fourteen days after such judgment, order, and determination shall have been obtained, enter upon the scite of the ground so ascertained for a party-wall or party-walls, party-arch or party-arches, and into the house or other building (if any be) adjoining to the house, or party-wall or party-walls, party-arch or party-arches, intended to be rebuilt, at any time between the hours of six in the morning and seven in the afternoon, (Sundays excepted,) and if the outer door of such house or other building be shut, and the occupier or any other person therein refuse to open the same, being thereunto required, or if such house or other building be empty and unoccupied, shall and may break open such outer door, and remove to some other part of the same premises, or in case there be no room on the premises sufficient for that purpose, to remove to any other place, any goods, furniture, shelves, or other thing obstructing the building of such intended party-wall or party-walls, party-arch or party-arches, or the pulling down any wall, partition, or other thing necessary to be pulled down and removed in order to the building such intended party-wall or party-walls, party-arch or party-arches; and from and after such entry as aforesaid, and at all usual times of working, it shall be lawful for the builder or builders employed to erect such intended party-wall or party-walls, party-arch or party-arches, and his and their servants, and all others employed by him or them, to enter into and upon the premises, and abide therein the usual times of working, for the shoring up the said house or other building so broke into or entered upon, and for taking down and removing any party-wall or party-walls, partition, wainscot, or other thing necessary to be taken down and removed for the purpose aforesaid, and to build such intended party-wall or party-walls, party-arch or party-arches; and if any such owner or occupier or other person or persons shall in any manner hinder or obstruct any workman or workmen employed for any of the purposes aforesaid, or wilfully damage or injure the said works, every such owner or occupier or other person so offending shall for every such offence forfeit and pay the sum of ten pounds, to be levied, recovered, and applied as the several penalties of ten pounds herein-after mentioned are directed to be levied, recovered, and applied.

Builders to be repaid a part of the expense according to the verdict.

XXXIV. Provided also, and it is hereby further enacted, that within ten days after such party-wall or party-walls, party-arch or party-arches, shall be so built, the person or persons who shall have rebuilt the same, his, her, or their executors, administrators, or assigns, shall leave a true account in writing of the expense of building the same with the party or parties so awarded by the jury as aforesaid to contribute to the expense thereof, or at his, her, or their last or usual place of abode; or in case such party or parties be under coverture, to her or their respective husbands; or if infants, idiots, or lunatics, then to their respective guardians, trustees, or committees; or in the case of any body corporate being so awarded to contribute as aforesaid, then to the mayor or other officer of such corporation, who shall pay to the person or persons who shall have rebuilt such party-wall or party-walls, party-arch or party-arches as aforesaid, his, her, or their executors, administrators, or assigns, the proportion of the expense of building the same so awarded by the said jury as aforesaid, within twenty-one days after demand thereof; or in case the same be not so paid, it shall be lawful for the tenant or occupier of the house or building so chargeable therewith to pay the same, and to deduct the money so paid out of the next rent which shall become due to the owner or owners of such house or building; or the same may be recovered from the party or parties so awarded to pay the same by action of debt, bill, plaint, or information in any of His Majesty's courts of record at Westminster, with double costs of suit.

Court of mayor and aldermen may be held in the outer chamber of Guildhall.

XXXV. Provided always, and it is hereby further enacted, that all the powers and authorities by this act vested in the court of mayor and aldermen of the city of London may be lawfully exercised by the court of mayor and aldermen of the said city, to be holden in the outer chamber of the Guildhall of the said city, according to the custom of the said city.

Sessions for Surrey to be holden at Southwark.

XXXVI. Provided always, and be it further enacted by the authority aforesaid, that upon every application to the general quarter sessions of the peace for the said county of Surrey for or concerning any matter to be by such quarter sessions ordered, directed, or done in pursuance of this act, the jury (if any) to be impannelled, and all parties required to attend the quarter sessions for the said county pursuant to such application, shall be impannelled and required to attend at some general or special adjournment of the said quarter sessions within six weeks next after such application, which said adjournment shall be to some convenient place in the borough of Southwark in the said county, to be appointed by the justices in the said sessions; and that from time to time every further meeting of the said sessions for any thing to be done upon such application shall be appointed at or within the space of three weeks from the last meeting; which adjournment and adjournments the justices of the peace for the said county of Surrey and every of them are hereby empowered and required to make and hold from time to time as there shall be occasion.

Court may fine the sheriff or under-sheriff making default, and also any witnesses making default.

XXXVII. And be it further enacted by the authority aforesaid, that it shall and may be lawful to and for the said court of mayor and aldermen, and to and for any or either of the aforesaid courts of sessions, (as the case may be,) and they are hereby empowered and required, from time to time to impose any reasonable fine or fines on any of the said sheriffs or sheriff, or their or his deputy or deputies, making default in the premises, and on any of the persons who shall be summoned and returned on such jury, and shall not appear at the time and place in such summons specified, or appearing shall refuse to be sworn on such jury, or to give his or their verdict, or in any manner wilfully neglecting his or their duty therein contrary to the true intent and meaning of this act, and on any of the persons having notice to attend to give evidence touching the premises who shall not attend, or attending shall refuse to be sworn, examined, and give evidence, and from time to time, in default of payment thereof on demand, to levy such fine or fines in such manner as other fines set by the said courts respectively have been usually levied, so that no fine shall exceed the sum of ten pounds upon any one person for any one offence; and such fine or fines, when so received or levied and recovered, shall be applied to and for the use of the person or persons so applying to the said court of mayor and aldermen, or to the said courts of sessions, (as the case may be,) and to and for no other use or purpose whatsoever; and if such person or persons having notice to attend and give evidence as aforesaid shall not attend and give evidence accordingly, having had ten days' previous notice in writing thereof under the hands of the party on whose behalf such evidence shall be wanted, his guardian, trustee, committee, attorney, or agent, and having been tendered his reasonable charges and expenses for such attendance, he, she, or they so neglecting or refusing to give evidence shall be liable to an action on the case to be brought against him, her, or them respectively by the party or parties on whose behalf any such notice to attend as aforesaid shall have been given, in which the plaintiff or plaintiffs shall recover their damages occasioned by such nonattendance, with full costs of suit; and such and no other justification or excuse shall be allowed for nonattendance as is by law allowable for the nonattendance of witnesses legally summoned to appear and give evidence on trials of issues joined in any of his Majesty's courts of record at Westminster; provided the court where such witness or witnesses shall appear may (if they shall think fit) order such further sum to be paid to such witness or witnesses respectively for their attendance on such courts respectively as to them shall seem reasonable, in proportion to the time such witness or witnesses shall attend, and such witness or witnesses shall not be compelled to give evidence before such further sum or sums (if any) as shall be so ordered shall be paid to them respectively.

Old party-walls and party-arches, when decayed, may be rebuilt;

the proprietors pulling down such party-walls or party-arches giving three months' notice.

XXXVIII. And whereas it may happen that party-walls or party-arches or party fence-walls, built or to be built within the limits aforesaid, may be defective, or so far out of repair as to render it necessary to pull down and rebuild the same, or some part or parts thereof, as well when both or either of the adjoining houses or other buildings may not require to be rebuilt as when the said houses or buildings, or one of them, may require to be rebuilt; be it enacted by the authority aforesaid, that from and after the said twenty-fourth day of June every owner of any house or building within the limits aforesaid who shall think it necessary to repair, pull down, or rebuild any party-wall or party fence-wall, or any part or parts thereof, between any such house or building, or the ground thereto adjoining, and the next adjoining house or building or the ground thereto adjoining, shall (in case the owner or owners of such adjoining house, building, or ground will not, or by reason of any legal disability or otherwise cannot, agree touching the repairing or pulling down or rebuilding the same,) give three months' notice in writing to the owner, if he is known and can be met with, or if such owner or owners be under coverture, to her or their husbands respectively, or if under the disability of infancy, idiotcy, or lunacy, to the guardian or guardians, trustee or trustees, committee or committees of such infant, idiot, or lunatic respectively, or otherwise to the occupier of such adjoining house, building, or ground, of such his or her intention to repair or pull down such party-wall, party-arch, or party fence-wall, or any part thereof, by delivering a copy of such notice to such owner or occupier or other person or persons as aforesaid, or by leaving the same at his, her, or their last or usual place of abode, or if such adjoining house or building be unoccupied, by fixing a copy of such notice on the door of such last-mentioned house or building; which notice shall be in the form or to the effect following:

The form of giving notice.

"Apprehending the party-wall, party-arch, or party fence-wall, or some part thereof, (as
"the case shall be,) between the house or building or ground (as the case shall
"be) thereto adjoining, situate , inhabited or occupied by ,
"and my house or building or ground (as the case shall be) adjoining thereto, to be so far
"out of repair as to render it necessary to repair or pull down and rebuild the same,
"or some part thereof: take notice, that I intend to have the said party-wall, party-arch,
"or party fence-wall (as the case shall be) surveyed, pursuant to an Act of Parliament
"made in the fourteenth year of the reign of King George the Third; and that I have
"appointed , of , and , of , my surveyors to meet at
" in (being at some place within the limits aforesaid) on my behalf,
"on the day of next, at of the clock in the of the same day (being
"between the hours of six in the morning and six in the afternoon); and I do hereby
"require and call upon you to appoint two other surveyors or able workmen on your part
"to meet them at the time and place aforesaid to view the said party-wall, party-arch, or
"party fence-wall, (as the case shall be,) and to certify the state and condition thereof, and
"whether the same or any part thereof ought to be repaired or pulled down and rebuilt.
"Dated this day of ."

Surveyors to be appointed to view party-walls and party-arches.

If the major part of the surveyors do not certify within one month, another surveyor to be named by a justice.

And every such owner, if he is known and can be met with, or in case such owner be under any disability as aforesaid, then such person or persons as aforesaid to whom such notice shall be so given, or otherwise the occupier to whom such notice shall be so given, shall appoint two surveyors or able workmen to meet at the time and place in such notice mentioned; and they, together with the two surveyors or workmen named by the party giving such notice, and whose names shall be expressed in such notice, may view such party-wall, party-arch, or party fence-wall, and certify the state and condition thereof, and whether the same or any part thereof ought to be repaired or pulled down and rebuilt; and such surveyors so respectively named as aforesaid, or in case the owner or occupier of such adjoining house or building, or such other persons as aforesaid having notice as aforesaid, shall refuse or neglect to name such two surveyors or able workmen according to such notice, then the two surveyors or workmen named in such notice, together with two other surveyors or able workmen also to be named by the party giving such notice as aforesaid, shall and may, within six days after the time appointed in such notice, view the party-wall, party-arch, or party fence-wall intended to be repaired or pulled down, and shall certify in writing under their hands to the said court of mayor and aldermen, or to the said justices of the peace in their next general or quarter sessions of the peace respectively, (as the case may be,) the state and condition of such party-wall, party-arch, or party fence-wall, and whether the same or any part thereof ought to be repaired or pulled down and rebuilt; and in case the major part of the surveyors or workmen appointed in manner aforesaid to view such party-wall, party-arch, or party fence-wall so intended to be repaired or pulled down shall not, within the space of one month next after such appointment, sign such certificate in writing, then and in every such case it shall and may be lawful to and for any one or more of His Majesty's justices of the peace for the said city of London, or county of Middlesex or Surrey, or city and liberty of Westminster, or liberty of His Majesty's Tower of London, (as the case shall be,) and such one or more justice or justices is and are hereby authorised and required, upon application to him or them for that purpose by the party giving such notice as aforesaid, to name and appoint one other able surveyor or workman to be added to the surveyors or workmen appointed as aforesaid; and all the said surveyors or workmen so appointed, or the major part of them, shall meet for that purpose, (six days' notice having been given to or left at the dwelling-house of each and every of them of such intended meeting,) and shall view the party-wall, party-arch, or party fence-wall so proposed to be repaired or pulled down; and in case the major part of such surveyors or workmen appointed in manner aforesaid shall certify in writing under their hands that the party-wall, party-arch, or party fence-wall described in such notice, or any part thereof, is decayed and ruinous, or is not sufficiently secure against fire if any should happen, and that the same ought to be repaired or pulled down, then, within three days next after such certificate made by such major part of the said surveyors or workmen as aforesaid, a copy thereof shall be delivered to the owner or occupier, owners or occupiers of or left at such adjoining house or building, or fixed on the door thereof in case the same be unoccupied; and such certificate shall be immediately filed with the clerk of the peace in the city, county, or liberty where such wall or arch is situate, paying such clerk one shilling for filing thereof, and no more; and such last-mentioned owner or occupier, owners or occupiers, shall and may (if he, she, or they think fit) appeal from or against such certificate to the next general or quarter sessions to be holden for the city, county, or place (as the case may be); and the justices at the said general or quarter sessions to which such appeals shall be made shall summon before them one or more of such surveyors or workmen, and such other person or persons as they think fit, and shall examine the matter upon oath, which oath or oaths they are hereby empowered to administer, and upon such examination or examinations the said justices are hereby authorised and required to make such order or orders in the premises as they in their discretions shall think to be just and reasonable; which order or orders shall be entered and filed of record by the clerk of the peace for the city, county, or place (as the case may be) in like manner as the judgments of any courts of sessions concerning intermixed property are herein-before directed to be entered and filed of record; and the determination of the said justices shall be final and conclusive to all parties, without any appeal from the same; and on default of appealing to such next general or quarter sessions as aforesaid, or if upon any appeal there be no order made to the contrary, then and in every such case, and not otherwise, it shall be lawful for the party intending to repair or pull down and rebuild such party-wall, party-arch, or party fence-wall as aforesaid, after the expiration of fourteen days after delivering or leaving the copy of such certificate as aforesaid, or after the determination of such appeal as aforesaid, to cause such party-wall, party-arch, or party fence-wall, or any parts thereof, to be repaired or pulled down, and to have and exercise the like power of entry into or upon the adjoining house or houses, building or buildings, or of breaking open the same, in the presence of a peace officer, in case the same be unoccupied or be refused to be opened, and of removing wainscot, shelves, furniture, and other things, and of shoring up the said adjoining house or houses, building or buildings, as is given or allowed to the owners of intermixed houses or buildings in and by this act, and shall and may erect and build a new party-wall or party-walls, party-arch or party-arches, or any part or parts thereof, of such materials, and of such thickness and height, and in such manner and subject to such restrictions and directions, as are in and by this act prescribed.

Walls being certified by the surveyors to be ruinous, a copy of the certificate to be delivered to the owners, &c. in three days.

Owners thinking themselves aggrieved may appeal to the general quarter sessions;

whose determination shall be final.

Powers of parties intending to repair, &c. in default of appeal.

XXXIX. And whereas several old houses and other buildings of the first, second, and third rate or class of building within the limits aforesaid have, instead of party-walls of the respective thicknesses herein-before directed for the same between such houses or other buildings and the adjoining houses or buildings, party-walls not being of greater thickness than one brick and an half in length, or thirteen inches, from the foundation to the ground floor thereof, or than one brick in length, or eight inches and an half, from thence to the coping thereof: And whereas disputes may arise concerning the pulling down such old party-walls, and concerning the building party-walls agreeable to the rules and directions herein contained in the place and stead of such old party-walls, whenever the owner or owners of any or either of the houses or buildings adjoining to any such party-walls may be desirous to rebuild any such house, or rebuild any such house or building, of the first, second, or third rate or class of building, or so much thereof as may subject the same, or the party-walls thereto, to the rules and regulations contained in this act; be it enacted by the authority aforesaid, that if the owner or owners of any house or building of the first, second, or third rate or class of building, to which any such old party-wall belongs, shall

Owners of houses of the first, second, and third class shall give three months' notice in writing before pulling down old party-walls.

be desirous of pulling down and rebuilding such house or building, or so much thereof as aforesaid, and of such his, her, or their desire shall give three months' notice in writing to the owner or owners, occupier or occupiers of the next adjoining house or building, of his, her, or their intention, in three months from the date thereof, to pull down such party-wall, and instead thereof to build a party-wall agreeable to this act of parliament, then and in that case, from and after the expiration of the three months expressed in such notice, it shall be lawful for the owner of such house or building so intended to be rebuilt to pull down the said party-wall, and to have and exercise the like power of entering into and upon the said adjoining house or building, or of breaking open the same, in the presence of a peace officer, in case the same be unoccupied or be refused to be opened, and of removing any wainscot, shelves, furniture, or other things, and of shoring up the said adjoining house or building, as by this act is given and allowed to the owners of intermixed houses or buildings, and shall and may, in the place and stead of every such old party-wall, build a new party-wall of such materials, thickness, and height, and in such manner and subject to such restrictions and directions, as are in and by this act prescribed.

Owners of houses having partitions of wood may give three months, notice to owners of adjoining houses of their design to pull down the same, &c.;

XL. And whereas several old houses or other buildings within the limits aforesaid have, instead of a party-wall between such house or other building, or between such houses or other buildings and the houses or other buildings and ground adjoining thereto, one timber or wood partition, or two old timber or wood partitions, with or without brick nogging, in one or more of the stories thereof, one belonging to each house or other building: And whereas disputes may arise concerning the pulling down such partitions, and the wall or walls under or over the same, if any such there be, and concerning the building party-walls, agreeable to the rules and directions herein contained, in the place and stead of such partition or fence, whenever it may be expedient to rebuild any such house or building, or so much thereof as may subject the same, and the partitions abutting on the same, to the rules and regulations contained in this act; be it enacted by the authority aforesaid, that if the owner or owners of any house or building to which any such timber or wood partition or partitions or wooden fence belongs shall be desirous of pulling down and rebuilding such house or building, or so much thereof as aforesaid, and of such his, her, or their desire shall give three months' notice to the owner or owners, occupier or occupiers of the next adjoining house or building, of his, her, or their intention to pull down such timber or wood partition or partitions after the end of three months after the date of such notice, and instead thereof to build a party-wall or party-walls agreeable to this act of parliament, then and in that case, from and after the expiration of the three months expressed in such notice, it shall be lawful for the owner of such house or building so to be rebuilt to pull down the said partition or partitions, and the wall or walls under or over the same, if any such there be, and the said wooden fence or fences, and to have and exercise the like power of entry into and upon the said adjoining house or building and ground, or of breaking open the same, in the presence of a peace officer, in case the same be unoccupied or be refused to be opened, and of removing any wainscot, shelves, furniture, or other things, and of shoring up the said adjoining house or building, as by this act is given and allowed to the owners of intermixed houses or buildings, and shall and may, in the place and stead of such partition or partitions, and of the wall or walls under or over the same, if any such there be, or of such wooden fence or fences, build a new party-wall or party-walls of such materials, thickness, and height, and in such manner and subject to such restrictions and directions, as are in and by this act prescribed.

and afterwards may pull down the said partitions, remove furniture, &c. as before directed.

How owners are to be reimbursed part of their expense, and in what proportion, who have built said partitions or party-walls.

XLI. And be it further enacted by the authority aforesaid, that the person or persons at whose expense any party-wall or party-arch shall be built agreeably to the directions of this act shall be reimbursed by the owner or owners who shall be entitled to the improved rent of the adjoining building or ground, and who shall at any time make use of such party-wall or party-arch, a part of the expense of building the same, in the proportion after mentioned; (that is to say,) if the adjoining building then erected or afterwards to be erected be of the same rate or class of building as or superior to the building belonging to the person or persons at whose expense the said party-wall was built, then the owner or occupier of such adjoining building or ground shall pay one moiety of the expense of building so much of the said party-wall or party-arch as such owner or occupier shall make use of; and if the adjoining building then erected or afterwards to be erected be of an inferior rate or class of building, then the owner or occupier of such adjoining building or ground shall pay a sum of money equal to one moiety of the expense of building a party-wall or party-arch of the thickness by this act required for the rate or class of building whereof such adjoining building shall be, and of the height and breadth of so much of the said party-wall or party-arch as such owner or occupier shall make use of; and in the mean-time, and until such moiety or other proportional part of the expense of

Until payment of expense the property of the building such party-wall or party-arch be so paid, the sole property of such whole party-wall or party-arch, and of the whole ground whereon the said party-wall shall stand, shall be vested entirely in the person or persons at whose expense the same shall be built; and such moiety or other proportional part of the expense of building such party-wall or party-arch shall be so paid to the person or persons at whose expense the same shall be built, or in whom the property thereof shall be vested, at the times herein-after mentioned; (that is to say,) in respect of every such party-wall to any house or building whereunto, at the time of building the same, no other house or building was adjoining, so soon as such party-wall shall be first cut into or made use of, and in respect of every such party-wall or party-arch as shall be built against or adjoining to any other house or building, so soon as such party-wall or party-arch shall be completely built and finished; and in respect of such last-mentioned party-wall or party-arch the owner or occupier of such adjoining house or building shall, together with such proportional part of the expense of building such party-wall or party-arch, also pay a like proportional part of all other expenses which shall be necessary to the pulling down the old party-wall or timber or wood partition, and the whole of all the reasonable expenses of shoring up such adjoining house or building, and of removing any goods, furniture, or other things, and of pulling down any wainscot or partition, and also all such costs, if any, as may have been awarded by the said court of mayor and aldermen, or court of sessions as aforesaid, but not any part of the expense of pulling down and clearing away any such old party-wall or party-arch or old partition, if any such there was; and it is hereby directed that the expense of building such party-wall or party-arch shall be estimated after the rate of seven pounds fifteen shillings by the rod for the new brickwork, deducting thereout after the rate of twenty-eight shillings by the rod for the materials (if any) of so much of the old wall or arch as did belong to such adjoining building or ground, and also after the rate of two-pence by the cubical foot for the materials (if any) of so much of the old timber partition as did belong to such adjoining building or ground; and that within ten days after such party-wall or party-arch shall be so built, or so soon after as conveniently may be, such first builder or builders shall leave at such adjoining house or building a true account in writing of the number of rods in such party-wall or party-arch for which the owner or owners of such adjoining building or ground shall be liable to pay, and of the deduction which such owner or owners shall be entitled to make thereout on account of such materials, and also an account of such other expenses and costs as aforesaid, whereupon it shall be lawful for the tenant or occupier of such adjoining building or ground to pay one moiety, or such proportional part as aforesaid, to such first builder or builders for the same, and also for shoring and supporting such adjoining building as aforesaid, and for all such other expenses as are herein-before directed to be paid by the owner or owners of such adjoining building or ground, and to deduct the same out of the rent which shall become due from him or her to such owner or owners under whom he or she holds the same respectively, until he or she shall be reimbursed the same; and in case the same be not paid within twenty-one days next after demand thereof, then the same shall and may be recovered, together with full costs of suit, of and from such owner or owners, by action of debt or on the case in any of His Majesty's courts of record at Westminster, wherein no essoign, protection, or wager of law, or more than one imparlance, shall be allowed; and if the plaintiff or plaintiffs in any such action shall, three calendar months at the least before the commencement thereof, give notice in writing to the person or persons against whom such action is intended to be brought, of his, her, or their intention to bring the same, or leave the same at his, her, or their last or usual place of abode, and shall in such notice specify the sum for which it is to be brought, and also annex to such notice a bill of the just and true particulars of the expenses and charges with which the intended defendant or defendants is or are to be charged, then such plaintiff or plaintiffs, if he, she, or they recover the full sum specified in such notice, shall also recover and be entitled to double costs of suit, and shall have and be entitled to the like remedies for recovery thereof as are usually given for costs in other cases of costs at law.

party-wall, &c. vested in the builder.

When a proportional part is to be paid.

Rates for building of party-walls.

Ten days after party-wall is finished an account to be left with the owner of adjoining buildings of what he is liable to pay.

How expenses may be recovered.

If the plaintiff before action gives three months' notice, and recover his whole charge, he shall be entitled to double costs.

XLII. And be it further enacted by the authority aforesaid, that every party wall hereafter to be built, and every addition which shall be made thereto, or to any party-wall which is already built or begun, shall be built agreeable to the directions herein contained concerning the party-wall of the highest rate or class of building to which such party-wall shall adjoin, when such additions are completed; and that no party-wall now built or hereafter to be built, shall, after the same and the buildings adjoining thereto is and are completed, be raised, unless the same, when raised, be of the full thickness such party-wall is of in the story next under the roof of the highest adjoining building, nor shall any party-wall hereafter be raised unless the same can be done with safety to such wall and the several buildings

Party-walls shall be such as are required for the highest rate of building adjoining, and not to be of less thickness;

may be raised by the owner of one side; and if the owner of the other side make use of it, he must contribute to the expense.

adjoining thereto; but all such party-walls as will when raised, be of the materials, heights, and thicknesses herein-before required, or as can be safely raised, may, together with the shaft or shafts of the chimneys belonging thereto, be raised, by and at the expense of the proprietor or occupier of any building to which the same belong, to any height he, she, or they shall think proper; but if the proprietor or occupier of any building adjoining to the said party-wall and chimney shafts shall make use of any part of such party-wall and chimney shaft, other than the use he makes of the chimney flues therein which shall be so raised, then such person so making use thereof for the part so used shall be chargeable with a proportionable share of the expense of raising such party-wall and chimney-shafts, and in computing such charge the same shall be rated in manner herein-before mentioned; and the proportion such person shall be liable to pay shall be recovered in such manner as is herein-before particularly declared concerning the first building of a party-wall.

Regulations as to party fence-walls.

XLIII. Provided always, that any party fence-wall now built or hereafter to be built may be raised by and at the expense of the proprietor or occupier of the ground on either side adjoining thereto; but no party fence-wall shall hereafter be built upon or against or used as a party-wall, unless the same be of the materials, height, and thickness herein-before directed for party-walls to the rate or class of building so to be erected against or upon the same; and in case of the insufficiency of such wall for the purposes aforesaid, or if instead of such party fence-wall there be only a wooden fence, the proprietor or occupier of either of the adjoining premises shall be at liberty, at his own expense, to take down such wall or fence, and erect a new party-wall in lieu thereof, making good every damage that may accrue to the adjoining premises by such rebuilding, so nevertheless as that such new party-wall shall not extend on the surface of such adjoining ground more than seven inches beyond the centre line of such party fence-wall or fence; but no proprietor or occupier of such adjoining premises shall make use of such party-wall, otherwise than as a party fence-wall, unless he, she, or they pay a proportionable share of the whole expense of erecting such parts of such wall, according to the use he, she, or they shall make of the same, at the rates aforesaid.

First builder not to lose any right of soil on account of party-walls.

XLIV. Provided also, that in case any such party-wall shall extend further upon the ground of the party building the same than the party fence-wall did, yet the party rebuilding the same shall not thereby lose any part of the soil whereon such party-wall shall be built, nor shall the owner or owners of the other part of such party-wall claim or be entitled to any right of soil more than what he was before entitled to.

If the fore and back fronts are taken down within five years, it shall be deemed a rebuilding.

Thickness of backs of chimneys not in party-walls.

Breast of chimney not to be supported by timber.

Timber under the hearth.

Hearth must be laid on brick or stone, or on the ground.

Slabs before hearths, and brick trimmers under them.

XLV. And be it enacted by the authority aforesaid, that if the fore-front and back-front of any building now built shall, after the said twenty-fourth day of June, be rebuilt as low as the bressummer or one pair of stairs floor, within the space of five years from each other, the party-walls of every such building shall from thenceforth be in all respects subject to the several regulations herein-before contained concerning the party-walls of houses to be built after the said twenty-fourth day of June; and for the further prevention of fire, the back of every chimney to be built, after the said twenty-fourth day of June, in any building of the first rate or class of building, not being in a party-wall, shall be in the cellar story at least thirteen inches thick from the hearth to the height of twelve inches above the mantel, and shall be at least eight inches and an half thick from the hearth to the height of twelve inches above the mantel in every other story, except where any such chimney shall be built against a wall, in which case the back of every such chimney from the hearth to the height of twelve inches above the mantel may be half a brick thinner; and that the back of every chimney hereafter to be built in any building of the second, third, or fourth rate or class of building, not being in a party wall, shall be in every story at least eight inches and an half thick from the hearth to the height of twelve inches above the mantel, except where any such chimney shall be built against a wall, in which case the back of every such chimney from the hearth to the height of twelve inches above the mantel may be half a brick thinner; and that there shall be no timber whatever over the opening of any chimney to be built after the time aforesaid for supporting the breast of such chimney, but there shall be an arch of brick or stone, or an iron bar or bars, over the opening of every such chimney, to support the breast thereof; and that no timber shall, after the said time, be laid in any wall under the hearth of any chimney thereafter to be built, unless the same shall be in every part thereof which shall lie under such hearth eighteen inches at the least lower than the surface of such hearth; and that the hearth of every chimney to be built after the time aforesaid shall be laid wholly on brick or stone, except the same be in a cellar or ground story, and be laid and bedded on the solid earth; and every such chimney shall have a slab or slabs or foot paces before the same of tile, stone, marble, or iron, at least eighteen inches broad, and at least one foot longer than the opening of every such chimney when finished, and such slab or slabs or foot paces shall be laid on brick or stone trimmers at least eighteen inches broad from the opening of such chimney, or from the perpendicular face of the arch over the opening which supports the breast of such chimney, except the same be in a cellar or ground floor, and be laid and bedded on the solid earth; and that no timber or wood-work whatever shall be laid in the brick-work of any oven, stove, copper, still, boiler, or furnace to be built after the said twenty-fourth day of June, nor within two feet of the inside of any such oven, stove, copper, still, boiler, or furnace; nor shall any timber whatever be laid in the brick-work of any chimney to be built after the said time nearer than nine inches to the opening of such chimney, or than five inches to the inside of the flue of any chimney, oven, stove, copper, still, boiler, or furnace, or than nine inches to the inside of the flue of any such oven, stove, copper, still, boiler, or furnace, where any such timber shall lie or be placed nearer than five feet above the mouth of the same; and that no wood-work whatever shall, at any time after the time aforesaid, be affixed to the front of any jamb or mantel, or to the front or back of any chimney or flue, except such wood-work be affixed by iron nails or holdfasts or other iron fastenings; and no iron nail, iron holdfast, or other iron fastening shall lie or be drove more than three inches into the wall against such chimney or flue, or nearer than four inches to the inside of the opening of any chimney; and that no chimney shall, after the time aforesaid, be erected on any timber-work whatever, except on such piling, bridging, or planking as may be necessary below the foundation of the building in which such chimney is erected, but every chimney thereafter to be built shall be erected on such piling, bridging, or planking, or on solid ground, or on a brick or stone foundation, or shall be set upon brick or stone corbels or iron brackets, or upon iron shores, which iron shores shall be supported by brick or stone foundations.

No timber in the brick-work of ovens, &c.

Distance of timber in the brickwork of chimneys, &c.

Wood-work on the front of chimneys.

No chimney to be erected on timber.

XLVI. And it is hereby further enacted, that every external wall or external inclosure of every building of the first, second, third, fourth, or fifth rate or class of building which shall be erected and built after the said twenty-fourth day of June, and of every addition or enlargement thereafter to be made to any building of the first, second, third, fourth, or fifth rate or class of building now erected or hereafter to be erected, shall be of brick, stone, artificial stone, lead, copper, tin, slate, tile, or iron, or of brick, stone, and such artificial stone, lead, copper, tin, slate, tile, and iron together, except the necessary piling, bridging, and planking for the foundation of the same, and also except the necessary templets, chains, bond timbers, and also except the doors, sashes, window shutters, and door and window frames to such buildings, and the tiers or stories of door cases and doors to all such warehouses as are or shall be of the first, second, third, or fourth rate or class of building; all which window frames and door frames shall be let in reveals, and recessed at least four inches from the front of the building in which such window frames and door frames shall be fixed; and also except the bressummers, story posts, and plates, which may be made on the ground story only, and also except all stall boards for the conveniency of any shop or shops which may be made on the ground story only; which bressummers, story posts, and plates, and the tiers or stories of door cases and doors to all such warehouses as before mentioned are not hereby required to be fixed in reveals; but no story post or bressummer shall, at any time after the said twenty-fourth day of June, be fixed more than two inches deep in any party wall, or be placed in any front nearer than seven inches to the centre line of the party-wall of such building if such party-wall be of the thickness of two bricks, or nearer than four inches and an half to the centre of such party-wall if such party-wall shall not exceed one brick and an half in thickness; but no timber-work whatever, other than and except such bressummer, story posts, and plates, and such tiers or stories of door cases and doors, shall be laid in any such external wall nearer than four inches to the external surface thereof; and every such story post which shall be fixed as a support to two fronts, being the corner of any street, square, place, court, or way, shall be of oak or stone, and at least twelve inches square.

Materials of external walls.

Sash frames and door frames to be in reveals.

Story posts and bressummers to be but two inches in party-walls.

Corner story posts to be of oak or stone, and twelve inches square.

XLVII. And be it further enacted by the authority aforesaid, that every flat, gutter, and roof of every building of the first, second, third, fourth, or fifth rate or class of building which shall be built after the said twenty-fourth day of June, and every turret, dormer, and lanthorn light, or other erection, which shall be placed in the flat or roof of any such building, and every external part of any flat, gutter, roof, turret, dormer, and lanthorn in any building of the first, second, third, fourth, or fifth rate or class of building, now built, and which shall at any time after the time aforesaid be ripped or uncovered, shall be covered with glass, copper, lead, tin, slate, tile, or artificial stone, except the doors, door frames, windows, and window frames of such dormers, turrets, lanthorn lights, or other erections.

Flats, roofs, &c. how to be covered.

XLVIII. And be it further enacted by the authority aforesaid, that every coping, Materials of external decorations.

Water how to be conveyed from roofs.

cornice, fascia, window dressing, portico, balcony, balustrade, or other external decoration or projection whatsoever to be made after the said twenty-fourth day of June to any building of the first, second, third, or fourth rate or class of building, and also every frontispiece to any building of the first rate or class of building now built or hereafter to be built, or to any addition or enlargement of any such building, shall externally be of brick, stone, burnt clay, or artificial stone, stucco, lead, or iron, except the cornices and dressings to shop windows, and also except such covered ways as may hereafter be made to any building, so nevertheless as that the said covered way or any part thereof shall not extend beyond the original line of the houses in the street or way in which the same shall be or is erected; and such covered way shall be covered with stone, lead, copper, slate, tile, or tin; and neither the said covered way, nor the cornice or dressings to any shop window, nor the roof of any such portico, shall be higher than the under side of the sill of the window frame of the one pair of stairs window of the building to which the same belongs; and that no water shall be suffered to drip next to any public street, square, place, court, or way from the roof of any building of the first, second, third, or fourth rate or class of building to be built after the said twenty-fourth day of June, except from the roofs of porticoes or other entrances, but all water from such roofs shall be conveyed by lead, copper, tin, or iron gutters or pipes, or all or either or any of them, or by wooden trunks, or by brick or stone funnels, to the drains or channel stones now made or hereafter to be made on or below the surface of the ground for that purpose, or to some cistern or other reservoir made to receive the same, or to any front of such building not abutting upon any public street or way; and no such brick or stone funnel shall, after the time aforesaid, be made or built unless the same shall be in every part thereof below the surface of the foot pavement before the same, nor shall any such wooden trunk after the said time be fixed unless the same be in every part thereof below the tops of the windows of the ground story.

No bow windows to extend beyond the line of the street, except projections for decorations.

Shop windows and stall boards.

Materials of bow windows and projections.

XLIX. And be it further enacted by the authority aforesaid, that no bow window or other projection shall, after the time aforesaid, be built with or added to any building of the first, second, third, or fourth rate or class of building, next to any public street, square, court, or way, so as to extend beyond the general line of the fronts of the houses in such public street, square, court, or way in which such bow window or other projection is made, except such projections as may be necessary for copings, cornices, fascias, door and window dressings, or for open porticoes, steps, or iron palisades; and also except such window to any shop or shops on the ground floor story of any such building, the stall boards of which windows shall not in any street or way thirty feet wide or more project above ten inches, nor in any street or way less than thirty feet wide above five inches, from the upright line of the building in such street or way respectively; and no cornice or covering thereof to any such shop window shall, in any street or way thirty feet wide or more, project more than eighteen inches, nor in any street or way less than thirty feet wide more than thirteen inches, from the upright line of the building to which such shop window belongs; and that no bow window or other projection, except as before excepted, shall, after the said twenty-fourth day of June, be built with or added to the front of any building of the first, second, third, or fourth rate or class of building, unless the same, and the columns and pilasters (if any) which support the same, be built of the several materials herein-before directed to be used in all external walls or external inclosures.

Saving to commissioners of paving.

L. Provided always, and be it enacted, that nothing herein contained shall prejudice, lessen, or defeat the powers granted to any commissioners for paving any streets or other places within the limits aforesaid by any act or acts of parliament, or to the commissioners of the sewers for the city of London.

Old external walls or inclosures may be repaired with the same materials.

LI. And be it further enacted by the authority aforesaid, that every external wall or other external inclosure to any building which is built or begun to be built before the said twenty-fourth day of June, not being of the several materials in and by this act required for external walls or external inclosures thereafter to be built, may be at all times thereafter repaired with the same sort or sorts of materials as the materials of which such external wall or other external inclosure is erected (except the external inclosures of roofs, flats, gutters, and of the dormers, turrets, and lanthorn lights or other erections on the same, which shall be repaired with the materials herein-before directed for the same); but in case any such external wall or other external inclosure be at any time hereafter taken down or otherwise demolished to the bressummer or one pair of stairs floor, or the place where the bressummer is usually fixed, then every part of the same, not being built of the several materials in and by this act required for external walls or other external inclosures thereafter to be erected, shall be taken down, and the same shall be entirely rebuilt of such materials, and in such manner in all respects, as in and by this act required for all external walls or other external inclosures thereafter to be built, according to the rate or class of building to which such wall or other external inclosure belongs.

No bow window or projection to be rebuilt, unless originally built, or within the line of the street, &c.

LII. And be it farther enacted by the authority aforesaid, that no bow window or other projection made or built before the said twenty-fourth day of June shall be at any time thereafter rebuilt, except such projections as are in and by this act allowed, unless such bow window or other projection was built at the same time the house or building to which the same belongs was built, or unless such bow window or other projection be within the original line of the street, square, place, court, or way in which the same is erected.

No stack of warehouses to be above thirty-five squares, including internal and external walls.

No communication through party-walls unless by stone door cases and iron doors.

LIII. And be it further enacted by the authority aforesaid, that no stack of warehouses to be erected after the said twenty-fourth day of June shall contain more than thirty-five squares of building on the ground plan thereof, including all the external and internal walls, and so much of the party-walls, if any, as belong to such stack of warehouses; and no enlargement shall be at any time thereafter made to any stack of warehouses already built or begun, so as to increase the same beyond the said thirty-five squares on the ground plan, including such walls as aforesaid, except such stack of warehouses be separated and divided by one or more party-wall or party-walls, built in every respect according to the directions herein-before contained concerning party-walls, into divisions of not more than thirty-five squares each, including such walls as aforesaid, on the ground plan of such warehouses; and that no stack of warehouses shall communicate with any other warehouse or building through a party-wall, unless the door case and sill of every such communication be of stone, and unless there be to every such communication a door of wrought iron of the thickness of a quarter of an inch at least in the panels thereof; and no timber, bond, or lintel shall be laid into the brick-work of any wall in any such stack of warehouses nearer than eighteen inches to the opening of such communication.

No stables to contain more than twenty-five squares of building, including internal and external walls.

No communication door without having stone cases, &c.

LIV. And be it further enacted by the authority aforesaid, that no building for stables to be erected after the said twenty-fourth day of June shall contain more than twenty-five squares of building on the ground plan thereof, including all the external and internal walls, and so much of the party-walls (if any) as belong to such building for stables; and no enlargement shall be at any time thereafter made thereto, or to any building for stables already built or begun to be built, so as to increase the same beyond the said twenty-five squares on the ground plan, including such walls as aforesaid, except such building for stables be separated and divided by one or more party-wall or party-walls, built in every respect according to the directions herein-before contained concerning party-walls, into divisions of not more than twenty-five squares each, including such walls as aforesaid, on the ground plan of such stables; and that no such building for stables shall communicate through a party-wall with any other stables or building, unless the door case and sill of every such communication be of stone, and unless there be to every such communication a door of wrought iron of the thickness of a quarter of an inch in the panels thereof; and no timber, bond, or lintel shall be laid into the brickwork of any wall in any such building for stables nearer than eighteen inches to the opening of such communication.

Buildings hereafter divided into distinct tenures on the ground floor deemed separate buildings.

LV. And be it further enacted by the authority aforesaid, that if any building whatsoever of the first, second, third, or fourth rate or class of building (except buildings in the several inns of court or chancery, the Royal Exchange, companies' halls, and except warehouses and dwelling-houses let at a rack-rent for not more than twenty-five pounds by the year,) be at any time hereafter converted into two or more dwelling-houses, workshops, stables, or other buildings, which shall be in distinct tenures on the ground floor thereof, then each such tenement shall be considered as a separate building, and the same shall be divided from each other by a party-wall or party-walls; and every such party-wall shall be of the materials, height, and thickness, and shall be from time to time under the several regulations respecting party-walls, herein directed to be observed with respect to the party-wall of the highest rate or class of building adjoining to such party-wall or party-walls.

Not to prevent proprietors from dividing warehouses;

LVI. Provided nevertheless, that nothing in this act contained shall extend to prevent any person, being the proprietor or leaseholder of any stack of warehouses, from dividing the said warehouses from time to time into divisions for the conveniency of letting the same to under-tenants, so nevertheless as that, if any stack of warehouses contain more than thirty-five squares of building on the ground plan, the same shall be separated and divided by a party-wall or party-walls as aforesaid into divisions of not more than thirty-five squares each, as is herein-before directed concerning stacks of warehouses to be erected after the said twenty-fourth day of June.

nor from dividing stables, subject to restrictions mentioned.

LVII. Provided also, that nothing in this act contained shall extend to prevent any person, being the proprietor or leaseholder of any stable yard or livery stables, from dividing the said stables from time to time into divisions for the conveniency of letting the same to under-tenants, so nevertheless as that, if any building for stables contain more than twenty-five squares of building on the ground plan, the same shall be separated and divided by a party-wall or party-walls as aforesaid into divisions of not more than twenty-five squares each, as herein-before directed concerning buildings for stables to be erected after the said twenty-fourth day of June

LVIII. And it is hereby further enacted, that if any building herein-before declared to be of the fifth or sixth rate or class of building be hereafter divided into two or more distinct tenures, and the several parts of such building in such separate tenures be not at the several distances from each other herein-before particularly directed for every such fifth or sixth rate building, then every such several part of such building in every such separate and distinct tenure, being nearer to each other than the said several distances, shall be deemed a public nuisance, and shall be immediately taken down as such.

Buildings of the fifth and sixth rates in distinct tenures, and not at the requisite distances, deemed nuisances.

LIX. And be it further enacted by the authority aforesaid, that no iron, tin, copper, or other pipe or funnel for conveying smoke or steam shall be at any time after the said twenty-fourth day of June fixed next any public street, square, court, or way, on the front of any building of the first, second, third, or fourth rate or class of building, nor shall any such pipe or funnel be fixed on the inside of any such building nearer than fourteen inches to any timber or other combustible material whatever, nor shall any brick funnel be thereafter built or placed on the outside of any front next to any public street, square, place, court, road, or way, of any building of the first, second, third, or fourth rate or class of building, so as to extend beyond the general line of the houses in the public street, square, place, court, or way in which the same is erected.

Restriction as to funnels for smoke in front or in the inside of houses of the first, second, third, or fourth rates.

LX. And be it further enacted by the authority aforesaid, that every church, chapel, meeting-house, dwelling-house, or other building, and every party-wall and other wall, which shall, after the said twenty-fourth day of June, be built within the limits of this act, shall be built pursuant to such rules and regulations, and with such materials, as are herein-before particularly appointed; and if any person or persons presume to build or to begin building, or cause the building or beginning to build, or to alter or cause to be altered any building already erected, in any respect contrary thereunto, and be thereof convicted by the oaths of two or more credible witnesses before the mayor of the city of London, or any two or more justices of the peace for the said city of London, or counties of Middlesex or Surrey, or city and liberty of Westminster, or liberty of His Majesty's Tower of London respectively, where such building contrary to the regulations aforesaid shall be situated, (which oaths they the said mayor and justices are hereby respectively empowered and required to administer,) then the said house, building, or wall so irregularly built or begun to be built, or so irregularly altered or begun to be altered, shall be deemed a common nuisance; and the builder and the owner thereof, or one of them, such as the said mayor or justices shall require, shall enter into a recognizance, in such sum as the said mayor or justices shall respectively appoint, for abating and demolishing the same within such convenient time as the said mayor or justices shall respectively appoint, or otherwise to amend the same according to such rules and regulations as are herein-before contained; and in default of entering into such recognizance, the person or persons so making default shall be committed to the common gaol of the city, county, or liberty where the offence shall be committed, there to remain without bail or mainprize until he shall have abated or demolished or otherwise amended the same, or until such irregular house or building shall be abated or demolished by order of such mayor or justices respectively, which order the said mayor and justices are hereby empowered to make; provided always, that such conviction be had within three months after such building shall be finished.

Every building contrary declared to be a common nuisance;

and the builder and owner to enter into a recognizance to demolish the same.

LXI. And it is hereby further enacted, that it shall be lawful for the mayor of the city of London, or any two or more justices of the peace for the said city of London, or county of Middlesex or Surrey, or city and liberty of Westminster, or liberty of his Majesty's Tower of London respectively, where any building contrary to the regulations aforesaid shall be situated, to order every house or building so irregularly built or begun to be built, or so irregularly altered or begun to be altered, as is by this act declared to be a common nuisance, to be abated or taken down, and to order the person or persons authorised to abate or take down the same to sell and dispose of the materials thereof, and out of the moneys arising by the sale thereof to pay to themselves, and all persons by them employed for the purposes aforesaid, the reasonable charges of abating or taking down such nuisance, and to pay the surplus of the monies arising by such sale (if any be) to the owner or owners of such materials; and if the moneys arising by such sale be not sufficient to pay such charges, the deficiency shall be made good by such owner or owners, and may be levied in like manner as is herein-after directed concerning the expense of taking down ruinous buildings, and putting up hoards for the safety of passengers.

Buildings deemed nuisances shall be taken down by order of the court, and may sell materials to defray the expenses.

LXII. And be it further enacted by the authority aforesaid, that the mayor and aldermen of the said city of London shall and may nominate and appoint such and so many discreet persons, skilled in the art of building, as they the said mayor

Court of aldermen of London to appoint surveyors in that city.

In other places the quarter sessions to appoint surveyors.

and aldermen think fit, to be, during their will and pleasure, the surveyors or supervisors to see the said rules and regulations well and truly observed in and throughout the said city of London and the liberties thereof; and it shall be lawful for the said mayor and aldermen in their court of aldermen, and they are hereby required, to administer to all the said surveyors or supervisors an oath for the true and impartial execution of their office in that behalf, and to appoint the several districts which shall be under their respective surveys; and it shall also be lawful for the justices of the peace for the county of Middlesex, the county of Surrey, the city and liberty of Westminster, and the liberty of his Majesty's Tower of London, in their general quarter sessions respectively, and they are hereby required, within their respective jurisdictions, to nominate and appoint such and so many discreet persons, skilled in the art of building, as the said justices in their respective quarter sessions think fit, to be, during their will and pleasure, the surveyors or supervisors to see the said rules and regulations well and truly observed in and throughout the said city and liberty of Westminster, and said several parishes, precincts, and places aforesaid within the jurisdiction of the respective quarter sessions by whom they shall be so appointed; and the said justices in their respective quarter sessions shall administer to the said surveyors and supervisors by them respectively appointed an oath for the true and impartial execution of their office in that behalf, and shall appoint the several districts which shall be under their respective surveys, which oath shall be in the form or to the effect following; that is to say,

Oath of surveyor.

" I, A. B., being one of the surveyors or supervisors appointed in pursuance of an act " of parliament passed in the fourteenth year of the reign of King George " the Third, for the further and better regulation of buildings and party- " walls, and for the more effectually preventing mischiefs by fire, within the cities of " London and Westminster and the liberties thereof, and other the parishes, precincts, and " places within the weekly bills of mortality, the parishes of Saint Mary-le-bone, Pad- " dington, Saint Pancras, and Saint Luke at Chelsea, in the county of Middlesex; and for " indemnifying, under certain conditions, builders and other persons against the penalties " to which they are or may be liable for erecting buildings within the limits aforesaid con- " trary to law, do swear, that upon receiving notice of any building or wall to be built, or " other builder's work to be done, within the district under my inspection, not being by " illness or otherwise lawfully prevented, I will diligently and faithfully survey the same, " and to the utmost of my abilities endeavour to cause the rules and regulations in the " said act prescribed to be strictly observed, and that without favour or affection, pre- " judice or malice. So help me God."

And such surveyor or supervisor shall from time to time leave notice in writing with the clerk of the peace for the county, city, or liberty in which his district shall be situated of the place of his usual abode or residence.

Surveyor to leave notice of his abode.

Notice of building to be given to surveyors.

LXIII. And it is also hereby further enacted, that before any building or any wall, on new or old foundations, or on foundations partly new and partly old, within the limits of this act, shall, after the said twenty-fourth day of June, be begun to be built, the master workman or other person causing such building or wall to be built shall give twenty-four hours' notice thereof to the surveyor or supervisor appointed as aforesaid within whose district the same shall be; and such surveyor or supervisor shall view the said building or wall, and see that all the rules and regulations in this act contained are well and truly observed; and such surveyor or supervisor, for his trouble therein, shall be paid by such master workman or other person causing such building or wall to be built such sum of money, as a satisfaction for his trouble therein, as any two or more of His Majesty's justices of the peace for the city, county, or liberty in which such building or wall is situate shall by any writing under their hands order or appoint, not exceeding three pounds ten shillings for every new building of the first rate or class of building, or one pound fifteen shillings for every first-rate building to which any alteration or addition shall be made; and not exceeding three pounds three shillings for every new building of the second rate or class of building, or one pound ten shillings for every second-rate building to which any alteration or addition shall be made; and not exceeding two pounds ten shillings for every new building of the third rate or class of building, or one pound five shillings for every third-rate building to which any alteration or addition shall be made; and not exceeding two pounds two shillings for every new building of the fourth rate or class of building, or one pound one shilling for every fourth-rate building to which any alteration or addition shall be made; and not exceeding one pound ten shillings for every new building of the fifth rate or class of building, or fifteen shillings for every fifth-rate building to which any alteration or addition shall be made; and not exceeding one pound one shilling for every new building of the sixth rate or class of building, or ten shillings and sixpence for every sixth-rate building to which any alteration or addition shall be made; and not exceeding ten shillings and sixpence for every new building of the seventh rate or class of building, or five shillings for every seventh-rate building to which any alteration or addition shall be made; and in default of payment of any of the said several sums of money, or such other sums as the said justices shall appoint, the same shall, by warrant of one or more of such justice or justices as aforesaid, be levied by distress and sale of the goods and chattels of such master workman or other person as aforesaid, together with the reasonable costs and charges of such distress and sale.

On default of notice, treble satisfaction to surveyor, and 20*l.* penalty.

LXIV. And it is hereby further enacted, that if any person shall, after the said twenty-fourth day of June, begin any such building or any such wall, or if any person or persons shall thereafter presume to cut into any party-wall, without first giving such notice as aforesaid to the surveyor or supervisor within whose district the same is situated, or shall refuse such surveyor or supervisor admittance from time to time, at reasonable hours, for the purpose of viewing the same, then every person so neglecting to give such notice, or so refusing such admittance, shall for every default therein forfeit and pay to the said surveyor or supervisor treble the satisfaction which such surveyor or supervisor would have been entitled to receive for his trouble in viewing such building or wall, and seeing the rules and regulations of this act well and truly observed therein, in case such notice had been given, and shall also for every such default forfeit the sum of twenty pounds, to be recovered by any action, bill, plaint, or information in any of His Majesty's courts of record at Westminster by any person or persons who shall sue for the same; and also every such house, building, or wall so begun to be built without giving such notice or without giving such admittance to such surveyor or supervisor, in case the same be not built in every respect agreeably to the regulations of this act, shall be demolished or amended by order of the said mayor, or of two justices within whose jurisdiction the same shall be, in the manner herein-before directed.

Surveyor to give information of irregular buildings.

LXV. And it is hereby further enacted, that in case the workmen employed in building any such building or wall, or in the cutting into any such party-wall, shall not well and truly observe the several rules and regulations in this act contained, and from time to time conform themselves thereto, the surveyor or supervisor within whose district the same is situated shall from time to time give information thereof as soon as conveniently may be to the said mayor of the city of London, or two or more justices of the peace within whose jurisdiction the same shall be; and the said mayor or justices shall proceed thereupon to hear the matter, and if any breach of the rules and regulations in this act contained is found to have been committed, the said mayor or justices shall proceed to cause such irregular building or wall to be demolished or amended in manner herein-before directed.

50*s.* penalty on workmen offending.

LXVI. And be it further enacted by the authority aforesaid, that if any workmen or servants to any master workman or other person or persons causing any such building or wall to be erected within the limits of this act shall wilfully, carelessly, or negligently, and without the direction, privity, or consent of such master workman or person causing such building or wall to be erected, do any thing in or about such building or wall contrary to the directions of this act, every such workman or servant so offending, upon conviction thereof before the mayor of London, or other justice of the peace for the said city of London, or before one or more justice or justices of the peace for the said county of Middlesex, or county of Surrey, or the city and liberty of Westminster, or the liberty of His Majesty's Tower of London, (as the case shall be,) upon the oath of one or more credible witness or witnesses, (which oath the said mayor and every such justice is hereby empowered and required to administer,) or upon his own confession, shall for every such offence forfeit the sum of fifty shillings, one moiety thereof to be paid to the overseer or overseers of the poor of the parish, precinct, or place wherein the offence was committed, for the use of the poor only, and the other moiety thereof to the informer; and if any such forfeiture of fifty shillings be not paid upon and immediately after such conviction, then the offenders shall, by warrant under the hand and seal of such mayor or other justice, be committed to the house of correction, there to remain without bail or mainprize for any time not exceeding three months or less than one month, unless the said penalty be sooner paid.

Houses or walls hereafter built to be surveyed within fourteen days after covered in, and oath made of their conformity to this act.

LXVII. Provided also, and it is hereby further enacted, that every master workman or other person who shall, after the said twenty-fourth day of June, build or cause to be built any house or other building, or any addition to any house or other building, or any party-wall or other wall, or who shall be employed to cut into any party-wall, within the limits of this act, shall, within fourteen days after such house or other building is covered in, or such party-wall or other wall is finished, or the cutting into any party-wall is made good, cause the same to be surveyed by the surveyor or supervisor within whose district the same is situated; and in case the said surveyor shall refuse, neglect, or shall, by illness or otherwise, be prevented surveying such building, wall, or other work, then the same shall be surveyed by any other surveyor or supervisor appointed and sworn within the city, county, or liberty wherein the said building, wall, or other work is situated; and if such surveyor or supervisor shall, upon such survey, find that the same is, to the best of his judgment and belief, built or made good agreeably to the several directions in this act contained, then such surveyor or supervisor shall, within fourteen days after surveying the same, make oath thereof by affidavit in writing before the mayor of the city of London, or some justice of the peace for the said city, or for the county of Middlesex, the county of Surrey, the city and liberty of Westminster, or the liberty of His Majesty's Tower of London respectively, within whose jurisdiction the said building or wall is situated, which oath such mayor or justice is hereby empowered and required to administer; and the said affidavit shall be filed with the clerk of the peace for the county, city, or liberty in which the said building or wall is situated within ten days after the making thereof; and the said clerk of the peace shall, for his trouble therein, be entitled to and receive the sum of one shilling and no more; and if any master workman or other person causing such building or wall to be erected, or such party-wall to be cut into as aforesaid, make default in the premises by neglecting to cause such survey to be made, or such affidavit to be made and filed, he shall for every such neglect forfeit the sum of ten pounds; and if such affidavit be not made and filed within the space of one month next after the recovery of such penalty, such master workman or other person as aforesaid shall forfeit the further sum of ten pounds, and so *toties quoties* for every month until such affidavit shall be made and filed; and each of the said penalties shall be recovered and applied in like manner as the penalty herein-after mentioned, and by this act inflicted on persons distilling or boiling larger quantities of turpentine together than are hereby allowed in places not hereby allowed.

Oath to be filed.

Builder neglecting to forfeit 10*l*.

Oath to be made within one month after conviction, on pain of further penalty of 10*l*.

LXVIII. Provided also, and it is hereby further enacted, that if any surveyor or supervisor appointed and sworn in manner herein-before directed shall at any time wilfully neglect his duty, or behave himself negligently or unfaithfully in the discharge thereof, and the same being, upon complaint thereof, made appear to the mayor and aldermen of the said city of London, or to the court of sessions by whom he was appointed, such surveyor or supervisor shall, by the said mayor and aldermen, or by the said court of sessions, (as the case may be,) be forthwith discharged from his said office, and shall for ever afterwards be incapable of being again appointed a surveyor or supervisor for the purposes aforesaid.

Surveyor on misbehaving to be discharged, and to be incapable of being again appointed.

LXIX. Provided also, and it is hereby further enacted, that nothing in this act contained shall extend to any of His Majesty's royal palaces, or to any house or building being in the possession of His Majesty, his heirs and successors, or employed for His Majesty's use or service, or to Her Majesty's palace, or to any house or building in the possession of Her Majesty, or employed for her use or service.

King's palaces, &c. excepted.

LXX. And whereas houses and buildings within the limits aforesaid are often, either from litigated titles thereto, or the obstinacy, neglect, or poverty of the owners thereof, or of the parties interested therein, in so ruinous a condition that passengers thereby are in danger of their lives or limbs from the falling thereof, or of the bricks or timber therefrom; be it therefore enacted by the authority aforesaid, that if any presentment shall hereafter be made by an inquest or grand jury in London, or by any annoyance jury within the city and liberty of Westminster, or by the jury sworn at the court leet held by the sheriff in his turn for any hundred or place, or by any other jury or inquest sworn within any other part of the limits aforesaid, that any house or building within the same limits or any part thereof is in a ruinous condition, it shall be lawful for the court of mayor and aldermen, in respect of any such house or building within the said city of London and the liberties thereof, or for the churchwardens or overseers of the poor for the time being of such parish, precinct, or place in which such house or building is situated, (not being in the city of London or the liberties thereof,) and the said court and every such churchwarden and overseer of the poor is and are hereby required, on notice of any such presentment being made, and a copy thereof being laid before them or him respectively, to cause, with all convenient speed, a proper and sufficient hoard to be put up for the safety of all passengers passing thereby, and to cause notice in writing to be given to the owner or owners, or other person or persons interested therein, if he, she, or they can be found, and if not to cause such notice in writing to be affixed to or upon the door or other notorious part of such house or building so presented to be in such ruinous condition, to repair the same, or to pull down such building, as the case may require, within fourteen days then next ensuing; and if such owner or owners, or other person or persons interested in any such house or building, do not begin to repair or take down the same within the said fourteen days after such notice so given or affixed as aforesaid, and complete such repairs or take down the same as soon as the nature of the case will admit, then, oath being made before the said mayor or a justice of the peace for the said city of London, or county of Middlesex or Surrey, or city and liberty of Westminster, or liberty of His Majesty's Tower of London, as the case may be, (which oath every of them the said mayor and justices is hereby empowered and required to administer,) of such notice having been so given or affixed as aforesaid, the said court of mayor and aldermen,

When any building is presented as ruinous, a hoard to be put up for safety of passengers.

If owners neglect to take down ruinous houses after notice, the mayor and aldermen, or overseers of the poor, may order the same to be taken down or secured;

and may sell the materials and satisfy themselves out of the monies arising by such sale.

by and out of the cash in the chamber of London, and also every such churchwarden and overseer of the poor, by and out of the monies in his hands, are hereby severally authorised and required, with all convenient speed, to order and cause such house or building so presented to be in a ruinous condition, or so much thereof as the said court, or the said churchwardens or overseers of the poor, find necessary for the safety of passengers, to be taken down and secured in such manner as shall from time to time be requisite, and to sell and dispose of such of the materials as the said court of mayor and aldermen, or the said churchwardens or overseers of the poor, shall judge necessary and expedient, and out of the monies arising by the sale thereof to reimburse, repay, and satisfy to themselves, and every person by them respectively employed for the purposes aforesaid, all the charges of putting up every such hoard, and of taking down or securing all and any part of every such house or building so taken down or secured as aforesaid, and of selling the said materials as aforesaid, or so much thereof as the monies arising by such sale will extend to pay, and shall account for and pay the surplus of the monies arising by such sale (if any be) to the owner of every such house or building, upon personal demand thereof made by such owner; and if no such demand be made of any such overseer or overseers before another or other overseer or overseers of the poor of the said parish, precinct, or place be appointed, then such overplus shall be added to the monies raised and collected by virtue of the rates made for the relief of the poor of the said parish, precinct, or place, and accounted for as such.

Overplus arising by the sale to be paid to owners any time within six years, on demand;

but if sale of old materials be insufficient, owners or occupiers to make good the deficiency.

Landlords to allow deficiencies paid by the tenants.

LXXI. Provided nevertheless, that any such owner, his or her executors or administrators, shall and may, at any time or times within the term of six years then afterwards, be entitled to have and receive such overplus from the churchwardens or overseers of the poor for the time being of such parish, precinct, or place within ten days after demand thereof personally made by such owner, his or her executors or administrators; and every such churchwarden or overseer is hereby required to pay the same accordingly out of any monies raised or to be raised by any rate or rates for the relief of the poor, and shall be allowed the payment thereof in any account to be by him made with the vestry, inhabitants, and parishioners of the said parish, precinct, or place, or the future overseer or overseers thereof; and if it happens that the monies arising by such sale shall fall short and are deficient to repay and satisfy all such charges, then such deficiency shall from time to time be paid by the owner or owners of every such house or building, if known and to be met with; and if such owner or owners, on demand thereof, neglect or refuse to pay the same, then such deficiency may be levied by warrant under the hand and seal of the mayor of the said city of London for the time being, or any other justice of the peace for the same city, or under the hands and seals of two or more justices of the peace for the county of Middlesex or county of Surrey, or city and liberty of Westminster, or liberty of His Majesty's Tower of London, (as the case shall be,) by distress and sale of the goods and chattels of such owner or owners, if any such can be found; and if no such owner or owners can be met with, or being met with shall not, on demand, pay the said deficiency, and no sufficient distress of his, her, or their goods and chattels can be met with wherefrom such deficiency of such costs and charges may be levied and recovered, then the person or persons who shall at any time then after occupy any such house or building, or the ground where the same stood, is and are hereby required and authorised to pay and deduct the same out of the rent thereof; and if he, she, or they neglect or refuse to pay such deficiency of charges, then the same shall, by warrant under the hand and seal of the said mayor of the said city for the time being, or any other justice of the peace for the same city, or under the hands and seals of two or more such justices of the peace as aforesaid, be levied by distress and sale of the goods and chattels of any occupier or occupiers of the premises, together with the costs of every such distress and sale; and the owner or owners of the premises is and are hereby required to allow to every such occupier or occupiers all such deficiencies and charges which he, she, or they shall so pay, or which shall be recovered or levied by distress and sale from him, her, or them as aforesaid, out of any rent which shall become due for the said premises or any part thereof; and every occupier paying any such deficiency and charges shall be acquitted and discharged for so much money as he, she, or they so pay, in the same manner as if the same had been actually paid to such person or persons to whom his, her, or their rents were due and should have been paid; and all money received or recovered on the account aforesaid, for or in respect of any such house or building within the city of London or the liberties thereof, shall be paid to the chamberlain of the said city, and be by him from time to time placed to the credit of the cash of the said city of London; and all money on the account aforesaid from time to time received or recovered for or in respect of any such house or building in any part of the limits aforesaid, other than the said city of London and the liberties thereof, shall be paid to the churchwardens or overseers of the poor for the time being of the parish, precinct, or place where such house or building so presented is situated, and shall be placed to the account of the said parish in aid of such or a like rate or fund out of which the expenses and charges so received or recovered were originally disbursed.

Not more than ten gallons of turpentine may be distilled at once in houses contiguous to others.

LXXII. And whereas the distilling turpentine, and the drawing off the oil of turpentine and rosin by distilling turpentine, and the boiling the said oil and turpentine together for making varnish, within the limits aforesaid, may prove of dangerous consequence to the neighbourhood where such practice is used; for preventing thereof for the future, be it enacted by the authority aforesaid, that from and after the said twenty-fourth day of June it shall not be lawful for any person or persons to distil or boil any turpentine, or to draw any oil of turpentine and rosin by distilling turpentine, or to boil any oil and turpentine together, above the quantity of ten gallons at one time, of all or any of the said commodities within the limits aforesaid, in any workhouse or place contiguous to any other building, or in any place nearer to any other building than the distance of fifty feet at the least, upon pain that every person offending therein shall for every such offence forfeit and pay the sum of one hundred pounds; every of which forfeiture shall and may be recovered, with treble costs of suit, by action of debt, bill, plaint, or information in any of His Majesty's courts of record at Westminster, wherein no essoign, protection, or wager of law, or more than one imparlance shall be allowed, one moiety whereof shall be to the use of the poor of the parish, precinct, or place wherein the offence was committed, and the other moiety thereof to such person or persons as shall inform or sue for the same.

Penalty.

Exception as to shipwrights, &c.

LXXIII. Provided always, that nothing in this act contained shall extend to prevent shipwrights, barge-builders, boat-builders, or mast-makers, or other persons employed in building or repairing ships, barges, boats, or other vessels near the river Thames, from boiling or mixing oil and other materials for the purpose of paying ships, barges, boats, or masts.

Fire engines and ladders to be kept in known places, and fire-cocks to be fixed on the mains.

LXXIV. And whereas the having a sufficient number of fire engines kept in known public places, and at convenient distances from each other, and ready to be brought forth as occasion may require, and the supplying such engines with plenty of water, and the giving encouragement to engineers and others to bring forth, use, and work such engines, may tend greatly to lessen the mischiefs happening by fire, and the having proper ladders kept in known public places ready to be brought forth may facilitate the escape of the inhabitants from houses on fire; be it enacted by the authority aforesaid, that from and after the said twenty-fourth day of June it shall and may be lawful to and for the churchwardens of every parish, and to and for the overseers of the poor of every precinct and place not having any churchwarden, within the limits aforesaid, and they are hereby respectively required, from time to time for ever to make, place, and fix at the charge of such respective parish, precinct, or place, upon the mains and pipes belonging to any waterwork whatsoever within the limits aforesaid, such and so many stopblocks of wood, with a wood plug, of such and so many firecocks to go into each main or pipe, and to be placed at such distances in each and every street or place, as such churchwardens or overseers of the poor respectively for the time being shall direct, and that the top of every such stopblock or firecock shall be even with the pavement of each street or place, to the intent such plugs or firecocks may upon occasion of any fire be opened to let out the water without loss of time in digging down to the pipes; and that all and every such churchwardens or overseers of the poor respectively shall have power and are hereby required from time to time to fix any mark or writing on the front of any house or houses over against or nearest to the place where such stopblocks, plugs, or firecocks respectively lie or are placed, for the better making known where all and every such stopblocks, plugs, or firecocks lie; and shall also keep an instrument or key in every such house where every such mark shall be to open the stopblock, plug, or firecock, and shall keep in such house a pipe for the water to come thereout to be made use of as occasion may require; and all such stopblocks and firecocks shall be kept in repair at the charge of each parish, precinct, or place where the same are placed, and such plugs shall be kept in repair by the owners of the mains and pipes where the same are fixed, and whenever the owners of any waterworks shall afterwards remove, change, or alter the said mains or pipes, then and in every such case the owner or owners of every such main or pipe shall, at his or their own proper costs and charges, place and fix the same or the like stopblocks, plugs, and firecocks upon every such new main or pipe, to be placed where the churchwardens of the parish, or overseers of the precinct or place not having a churchwarden, for the time being shall direct; and in every such case the instrument or key and pipe shall be removed to the house opposite or nearest to the place to which such stopblock, plug, and firecock is removed, and every such churchwarden or overseer respectively shall cause a like mark or writing to be fixed against every such house.

Marks to be placed near the place where fire-cocks lie.

Instrument or key to be kept there.

Engines and ladders to be kept by every parish.

LXXV. And be it further enacted by the authority aforesaid, that every parish within the limits aforesaid shall from time to time and at all times, after the said twenty-fourth day of June, have and keep in good order and repair, and in some known and public place within each parish, a large engine and also a hand engine to throw up water for the extinguishing of fires, and also shall provide, keep, and maintain one leather pipe at least, with a socket of the same size as the plug or firecock, and a standcock or suction pipe, to the intent the socket may be put into the pipe to convey the water without loss, and without the help of buckets, into the engine, and shall also have and keep in some known and public place within each parish three or more proper ladders, of one, two, and three story high, for assisting persons in houses on fire to escape therefrom; and in default of making, placing, fixing, and continuing such stopblocks or firecocks on the several mains and pipes, as also in default of having and keeping in good repair such large engine, hand engine, and leather pipe or pipes, socket and standcock and suction pipe, and such ladders as aforesaid, every churchwarden of such parish, and every overseer of any such precinct or place not having a churchwarden, making default in all or any of the premises, and being convicted thereof before two of His Majesty's justices of the peace for the said city of London, or for the county of Middlesex or Surrey, or liberty where the same may happen, (as the case may be,) shall forfeit and pay the sum of ten pounds, one moiety thereof to the informer, and the other moiety thereof to the surveyor or surveyors who shall be then appointed, pursuant to this present act of parliament, for the district within which such parish, precinct, or place where such default shall be made doth lie, to be levied and recovered by distress and sale of the goods and chattels of such churchwardens and overseers respectively so convicted of such default as aforesaid.

10*l.* penalty on churchwardens for default, which may be levied by distress.

Fees to the turncock whose water first comes into a main or pipe at a fire;

to the engine-keeper;

to the second engine-keeper;

and to the third engine-keeper.

LXXVI. And be it further enacted by the authority aforesaid, that the turncock belonging to the waterwork whose water shall be found on or shall first come into the main or pipe where any plug shall be opened at any fire within the limits aforesaid shall be paid any sum not exceeding ten shillings by the churchwardens or overseers of the poor of such respective parish, precinct, or place where such fire may happen; and that the engine-keeper which first brings a parish engine, or other large engine, to help to extinguish any fire happening within the limits aforesaid, if in good order and complete, with a socket, hose, leather pipe, standcock, and suction pipe, shall be paid any sum not exceeding thirty shillings; the keeper of the second parish engine or other large engine which shall be next brought, in such order and so complete, to help to extinguish any such fire, shall be paid any sum not exceeding twenty shillings; and the keeper of any parish engine or other large engine which shall be the third of such engines brought, in such order and so complete, to any such fire, shall be paid any sum not exceeding ten shillings; every such payment to be made by the churchwardens of each parish, or by the overseers of the poor of every such precinct or place not having any churchwarden (as the case may be) where any such fire shall happen; and in default of payment thereof, such reward shall be levied and recovered from the said churchwardens and overseers respectively by distress and sale of the goods and chattels of every such churchwarden and overseer in the same or like manner as the penalty or forfeiture of ten pounds is herein-before directed to be levied and recovered.

But no reward to be paid without the approbation of an alderman, &c.

LXXVII. Provided always, and it is hereby further enacted by the authority aforesaid, that no such reward shall be paid to any turncock or engine keeper by the churchwarden of any parish, or overseer of the poor of any precinct or place aforesaid, where any fire may happen, without the approbation and direction of the alderman of the ward wherein such parish, precinct, or place is situate, or his deputy, or of two of the common councilmen of the same ward for the time being, if such fire happens within the city of London or the liberties thereof, or without the approbation and consent of one or more justice or justices of the peace in and for the said county of Middlesex or county of Surrey, or liberty where the same may happen, (as the case may be,) residing within such parish, precinct, or place where such fire happens, and if there be not any justice or justices of the peace residing in such parish, precinct, or place, then of such justice or justices of the peace residing in the parish or place near or next adjoining if such fire happens any where within the limits of this act out of the said city of London and the liberties thereof.

Where any rewards for chimneys on fire have been paid by the churchwardens, they are to be reimbursed by occupiers, as the mayor, &c. shall direct.

LXXVIII. And whereas many of the parishes within the limits of this act have been frequently put to considerable expenses, occasioned by the neglect of the inhabitants, as well lodgers and inmates as housekeepers, in not causing their chimneys to be duly swept, by means whereof alarms of fire are frequently made, to the great terror and danger of His Majesty's subjects, which probably would be prevented if such inhabitants were obliged to defray and bear the charges and expenses attending such their neglects, or some reasonable part thereof; be it therefore enacted by the authority aforesaid, that from and after the said twenty-fourth day of June, in all cases where any reward or rewards, or other recompence by this act made payable, shall be borne and paid by any churchwarden or overseer of the poor for or on account of any fire being in a chimney only, or first beginning in and occasioned by the taking fire of any chimney only, the inhabitant or inhabitants, occupier or occupiers of any room or apartment to which any such chimney belongs, being a lodger or inmate to or with any tenant, renter, or holder of any house or building of which such room or apartment is part, or if such chimney belong not to any such lodger or inmate, then the tenant, renter, or occupier of the house or building wherein any such fire as last mentioned first begins, shall reimburse and repay to the churchwarden or overseer of the poor all and every such reward and rewards or other payments by him or them made pursuant to the directions of this act, or such part thereof as the mayor or other justice of the peace of the said city of London, or justice of the peace for the liberty of His Majesty's Tower of London, or justice of the peace for the county of Middlesex or county of Surrey, or for the city and liberty of Westminster, (as the case may be,) upon the application and complaint of such churchwarden or overseer of the poor, and hearing the party or parties complained against, shall under his hand and seal award and direct; and to the end the said mayor or other justice aforesaid may be the better enabled to award and direct what may in any such case be just and reasonable, the said mayor for the time being and every such justice shall and may summon before him, after any such complaint made, the party and parties complained against, and all persons fit to give evidence touching the premises of whom he shall have notice or information, and shall and may examine them and every of them upon oath, (which oath the said mayor and every such justice is hereby empowered and required to administer without fee or reward;) and if the party or parties complained against, being summoned, do not appear, the said mayor and every such justice of the peace shall and may proceed to examine the matter of the complaint and such evidence as is produced, and to make such award and direction thereupon as shall be just, and as if the party or parties making such default of appearance had been present, and heard in his, her, or their defence; and if any sum or sums of money so awarded and directed to be reimbursed or repaid to any such churchwarden or overseer of the poor be not so reimbursed or repaid within fourteen days after demand thereof made, it shall and may be lawful to and for every such churchwarden or overseer, by warrant under the hand and seal of such mayor or other justice, (which warrant the said mayor and every such justice is hereby authorised to make,) to levy every such reward and rewards or other recompence so paid, or such part thereof as shall have been so awarded and directed, by distress and sale of the goods and chattels of the party or parties making default of payment, or of any goods or chattels found in the room or apartment to which such chimney where such fire began belongs, or in any other part of any house or building whereof such room or apartment is part.

To enable justices to execute their duty.

United parishes to be deemed one.

LXXIX. And forasmuch as several of the parishes within the city of London were, after the great fire which happened in the year of our Lord Christ one thousand six hundred and sixty-six, united together; be it enacted by the authority aforesaid, that any two or more of the said parishes so united shall, for the purposes of this act, be deemed one parish only.

Large parishes may have more than one large engine, &c.

LXXX. Provided nevertheless, and it is further enacted, that in case the vestries of any of the said united parishes, or of any other parish within the limits aforesaid, at any time conceive it necessary for the said parish, in respect to the largeness thereof, to have more than one great engine or hand engine, it shall and may be lawful for them to provide two or more great engines or hand engines at the parish charge; and that the same engines and every of them shall be under the like regulations and encouragements as the other engine or engines directed to be provided by this act are under.

Fire engines, &c. to be paid for out of the poor's rates.

LXXXI. And in order to raise money to defray the necessary charges of providing and maintaining such engine, stopblocks, and firecocks and keys, and other implements and materials, and such ladders as aforesaid, and the payment of the rewards or gratuities directed by this act, be it enacted by the authority aforesaid, that the churchwardens and overseers of the poor of the said several parishes, precincts, and places within the limits of this act, or the major part of them, with the consent of the majority of such inhabitants as shall be, at any vestry or other public meeting of such parish, precinct, or place, duly assembled, shall and may from time to time, (as often as there may be occasion,) out of the monies raised or received or to be raised or received by any rate or rates made or to be made for relief of the poor of every such parish, precinct, or place respectively, or by any special rate or rates to be made for the purposes of this act, pay, apply, and dispose of such competent sum and sums of money as may be requisite for the ends aforesaid, in like manner as by law they may do for the maintenance and relief of the poor of their respective parishes, precincts, or places; and every such special rate or rates which shall be made as aforesaid, the same being allowed and confirmed in the like manner as the rates made for the relief of the poor are or ought to be allowed or confirmed, shall be levied and recovered in the same manner as the rates made for the relief of the poor now may or ought to be levied and recovered, subject to the like appeal as in cases of rates made for the relief of the poor; and the said officers shall be accountable for the same in like manner as they are accountable for the money by them collected for the relief of the poor, and shall be liable to the like pains and commitments for not accounting for the same, and to the like distress and penalties for not paying the monies by them collected, levied, or received, and remaining in their hands, as overseers of the poor are, by all or any of the laws of this land, liable to for not accounting for or not paying monies collected by virtue of any rates for relief of the poor.

Watermen retained by insurance offices not to be impressed.

LXXXII. And whereas the several offices for insuring houses against loss by fire retain in their several services, and give coats and badges and other rewards unto, watermen, for the service and assistance in and towards extinguishing of fire, and who are to be always ready when wanted, and are provided with various sorts of poles, hooks, hatchets, and several other instruments and things, at the charges of the said respective insurance offices, for the extinguishing of fire, which watermen so retained are by experience found to venture much further and to have skill to give, and do give, at fires happening within the limits aforesaid, greater help than other persons not used to come into danger; be it further enacted by the authority aforesaid, that the watermen for the time being so retained by and belonging to every such insurance office within the limits aforesaid, not exceeding thirty for each office, shall be free from being impressed, or liable to be compelled to go to sea, or serve as mariners, or as soldiers on land, their names and places of abode being registered and entered with the secretary or other officer of the Admiralty Office.

Money insured on houses burnt how to be applied.

LXXXIII. And in order to deter and hinder ill-minded persons from wilfully setting their house or houses or other buildings on fire, with a view of gaining to themselves the insurance money, whereby the lives and fortunes of many families may be lost or endangered, be it further enacted by the authority aforesaid, that it shall and may be lawful to and for the respective governors or directors of the several insurance offices for insuring houses or other buildings against loss by fire, and they are hereby authorised and required, upon the request of any person or persons interested in or entitled unto any house or houses or other buildings which may hereafter be burnt down, demolished, or damaged by fire, or upon any ground of suspicion that the owner or owners, occupier or occupiers, or other person or persons, who shall have insured such house or houses or other buildings, have been guilty of fraud or of wilfully setting their house or houses or other buildings on fire, to cause the insurance money to be laid out and expended, as far as the same will go, towards rebuilding, reinstating, or repairing such house or houses or other buildings so burnt down, demolished, or damaged by fire, unless the party or parties claiming such insurance money shall, within sixty days next after his, her, or their claim is adjusted, give a sufficient security to the governors or directors of the insurance office where such house or houses or other buildings are insured that the same insurance money shall be laid out and expended as aforesaid, or unless the said insurance money shall be in that time settled and disposed of to and amongst all the contending parties to the satisfaction and approbation of such governors or directors of such insurance office respectively.

Servants by carelessness firing a house to forfeit 100*l.* or be imprisoned eighteen months.

LXXXIV. And whereas fires often happen by the negligence and carelessness of servants; be it therefore enacted by the authority aforesaid, that if any menial or other servant or servants through negligence or carelessness shall fire or cause to be fired any dwelling-house or outhouse or houses or other buildings, whether within the limits aforesaid or elsewhere within the kingdom of Great Britain, such servant or servants, being thereof lawfully convicted by the oath of one or more credible witness or witnesses made before two or more of His Majesty's justices of the peace, shall forfeit and pay the sum of one hundred pounds unto the churchwardens or overseers of such parish where such fire shall happen, to be distributed amongst the sufferers by such fire in such proportions as to the said churchwarden shall seem just; and in case of default or refusal to pay the same immediately after such conviction, the same being lawfully demanded by the said churchwardens, that then and in such case such servant or servants shall, by warrant under the hands and seals of two or more of His Majesty's justices of the peace, be committed to the common gaol or house of correction, as the said justices shall think fit, for the space of eighteen months, there to be kept to hard labour.

Constables and beadles, on notice, to repair to buildings on fire.

LXXXV. And be it further enacted by the authority aforesaid, that upon the breaking out of any fire within the limits aforesaid, all constables and beadles upon notice thereof shall immediately repair to the place where the said fire shall happen, with their staves and other badges of their authority, and shall be aiding and assisting as well in extinguishing the said fires and causing people to work at the engines, as also in preventing goods being stolen, and shall seize and apprehend all ill-disposed persons that they shall find stealing or pilfering from the inhabitants, as also that the said constables and beadles shall give their utmost assistance to help the inhabitants to remove their goods.

LXXXVI. And be it further enacted by the authority aforesaid, that no action, suit, or process whatever shall be had, maintained, or prosecuted against any person in whose house, chamber, stable, barn, or other building, or on whose estate, any fire shall, after the said twenty-fourth day of June, accidentally begin, nor shall any recompence be made by such person for any damage suffered thereby, any law, usage, or custom to the contrary notwithstanding: and in such case, if any action be brought, the defendant may plead the general issue, and give this act and the special matter in evidence at any trial thereupon to be had; and in case the plaintiff become nonsuited, or discontinue his action or suit, or if a verdict pass against him, the defendant shall recover treble costs; provided that no contract or agreement made between landlord and tenant shall be hereby defeated or made void.

No action to lie against a person where the fire accidentally begins.

LXXXVII. And be it further enacted by the authority aforesaid, that where any distress shall be made for any sum or sums of money to be recovered by virtue of this act the distress itself shall not be deemed unlawful, nor the party or parties making the same be deemed a trespasser or trespassers, on account of any defect of form in any proceedings relating thereto, nor shall the party or parties be deemed a trespasser or trespassers *ab initio* on account of any irregularity afterwards done by the party or parties making such distress, but the person or persons aggrieved by such irregularity may recover full satisfaction for the special damage only by action on the case, and not by any other action whatsoever.

Distress not unlawful for want of form, &c.

LXXXVIII. Provided always, and be it further enacted by the authority aforesaid, that no plaintiff or plaintiffs shall recover in any action for any such irregularity or other proceedings if tender of sufficient amends be made, by or on the behalf of the party or parties who committed or caused to be committed any such irregularity or wrongful proceeding, before such action be brought; and in case no such tender shall have been made, it shall and may be lawful for the defendant or defendants in any such action, by the leave of the court where such action shall depend, at any time before issue joined, to pay into the court such sum of money as he or they shall see fit, whereupon such proceedings or order and judgment shall be had, made, or given in and by such court as in other actions when the defendant is allowed to pay money into court.

Plaintiff not to recover if tender of sufficient amends be made, &c.

LXXXIX. And whereas by the said recited act of the twelfth year of his present Majesty's reign various penalties are inflicted upon persons who should offend against the said act: and whereas since the passing the said act there has been a great increase of buildings within the limits aforesaid, and many of such buildings are not in every respect built according to the directions of the said act, whereby various penalties have been incurred, and several persons are or may be under prosecution for the same: and whereas the owners of such buildings, and several builders or workmen employed therein, are respectively willing to make the same as secure against fire, and as conformable to the directions contained in this act, as the nature of each case will admit; be it therefore enacted by the authority aforesaid, that in every action, bill, plaint, suit, or information now depending or that shall hereafter depend in any of His Majesty's courts of record at Westminster against any such owner, builder, or workman, or person or persons causing any such building to be erected or built, or any other person or persons, for the recovery of any penalty incurred or supposed to be incurred by the said act, it shall be lawful for the court where the same is or may be depending, and such court is hereby required and empowered, on the application of the respective defendants, to make a rule for the plaintiff in any such action, bill, plaint, suit, or information to deliver to such defendant or defendants, or his, her, or their attorney in the cause, an account in writing, under the hands of the plaintiff or his attorney, of the particular defect or irregularity in every such building whereby each penalty is incurred or supposed to be incurred, and to make an order for staying the proceedings in such action, suit, or information, until such account in writing shall be delivered; and after such account shall have been delivered as aforesaid, it shall and may be lawful to and for such defendant or defendants either to defend such action or actions as if this act had not been made, or otherwise, in case he or they shall not choose to defend the same, to enter into a rule of the same court for making good or reforming such irregularities and defects (if any), and for rendering such building as secure against fire, and as conformable to the directions of this act, in such manner and within such time as two or more of the surveyors herein-before directed to be appointed in the county, city, or liberty wherein the same is situate shall by any writing under their hands direct and appoint; and upon such rule being entered into by such defendant or defendants, and on payment to the plaintiff of the costs in such action, suit, or information, to be taxed by the proper officer of such court, the said court shall order all further proceedings to be stayed in such action, suit, or information until the time appointed by the said surveyors for the purposes aforesaid shall be expired; and after the expiration thereof, such court is hereby required and empowered, on application or motion by or on the behalf of such owner, builder, or workman, or other person or persons aforesaid, and on proof by affidavit to the

Prosecutions on 12 G. III. c. 73. discharged on amending buildings in such manner as shall be directed by two of the surveyors.

Rule being entered into by defendant, all proceedings to be stayed, &c.

satisfaction of such court that the defects and irregularities complained of are made good or reformed, and the building of such house or houses rendered as secure against fire, and as conformable to the directions of this act, in such manner and within such time as such two or more of the said surveyors or supervisors shall have appointed by such writing as aforesaid, to order proceedings to be peremptorily stayed in such action, suit, or information; and the defendant or defendants shall from thenceforth be for ever indemnified and discharged of, from, and against all penalties and forfeitures incurred or to be incurred for or by reason of not having originally built such party-walls or buildings pursuant to the directions of the said act, or for or by reason of any other defect or irregularity whereby such houses or party-walls are otherwise built than pursuant to such directions, any thing in the said act contained to the contrary notwithstanding.

Defendant indemnified from all forfeitures, &c.

Proviso.

XC. Provided, that if no such application shall be made to court before the end of the next term after the expiration of such time as shall be appointed by the said surveyors as aforesaid for the purposes aforesaid, or if upon such application as aforesaid such proof shall not be made by the defendant or defendants to the satisfaction of the said court as aforesaid, then the said plaintiff or plaintiffs shall be at liberty to proceed in such suit as if this act had not been made.

How the court shall proceed where any rule shall be entered into, &c.

XCI. And it is further declared by the authority aforesaid, that the court or courts where any such rule as aforesaid shall be entered into pursuant to the directions in this act contained shall and are hereby required to proceed against the party or parties who shall have entered into any such rule, and have refused or neglected to perform the same, as for a contempt of the said court, and shall on motion issue the like process of attachment, or otherwise, as is usually issued against any suitor or suitors of such court for contempt of a rule of court.

Not to extend to indemnify persons against whom judgment shall be given, &c.

XCII. Provided always, that this act or anything herein contained shall not extend to indemnify any person against whom final judgment shall have been given before the passing of this act in any action of debt, bill, plaint, or information in any of His Majesty's courts of record, grounded on the said act made in the twelfth year of his present Majesty's reign, for the recovery of any penalty inflicted by the said act.

Irregular buildings erected since 12 G. III. to be made secure against fire, and irregular projections to be altered, though no prosecutions have been commenced.

XCIII. And whereas since the passing the said act made in the twelfth year of his present Majesty's reign many houses and other buildings have been erected within the limits aforesaid not conformable to the regulations of the said act, but no prosecutions have been and probably may not be commenced against the builders thereof: and whereas it is reasonable that the same should be made as secure against fire and as conformable to the directions in this act as the nature of each case will admit: and whereas wooden buildings have been erected on the tops and other parts of houses, and many bow-windows and projections have been made, contrary to the said act, though no prosecutions have been nor may probably be commenced for any penalties thereby incurred: and whereas such wooden buildings as have been so erected on the tops or other parts of the said houses, and such bow-windows or projections, ought to be taken down and removed, or some alterations or amendments ought to be made therein; be it therefore enacted by the authority aforesaid, that if any three or more surveyors or supervisors, to be appointed and sworn in manner herein-before directed, shall certify in writing under their hands to the court of mayor and aldermen of the city of London, or to the court of quarter sessions within whose jurisdiction any such house or building is situated, that any house or building has been erected since the passing the said act within the limits aforesaid not conformable to the said act, or that any such wooden building has been erected on the tops or other parts of houses, or that any bow-windows or projections have been made contrary to the said act, for which no prosecutions have been commenced, so as to bring them within the provision herein-before made respecting the same, and shall certify in what manner the same may be reformed, it shall be lawful for the said court of mayor and aldermen or court of quarter sessions respectively within whose jurisdiction the said house or building or bow-window or projection is situated, if they think fit, to make an order for amending or reforming such house or building accordingly, and for making the same more secure against fire, or more nearly conformable to the regulations of this act, and for taking down and removing or for altering or amending such wooden buildings and such bow-windows or projections as aforesaid by the master builder or master bricklayer or master workman or person who caused the same to be erected, who shall be expressly named in such order; and every such order of the said court of mayor and aldermen or court of sessions shall be by the town clerk of the city of London, or by the clerk of the peace, (as the case may be,) entered and filed as of record in the said court where such order was made, for the entry and filing whereof, and for every copy thereof, the said town clerk or clerk of the peace shall be paid by the person applying for the same the sum of one shilling and no more if the same do not exceed one hundred words, and if the same exceed one hundred words, then after the rate and pro-

Court to make an order for reforming irregular projections.

Order to be filed.

portion of one shilling for every one hundred words; and a copy of the said order shall be delivered to the said person or persons in the said order named, or shall be left at his or their last or usual place of abode, or with the tenant in possession of the house or building in the same order mentioned, or shall be affixed upon the door or other notorious part of the said house or building; and within the space of nine months next after the copy of such order shall have been so delivered or left or affixed as aforesaid the said person or persons therein named shall make good all the defects and irregularities in such order specified, and either take down and entirely remove such wooden building or buildings or bow-window or projection, or otherwise alter, reform, or amend the same in such manner as shall be directed by such order; and in case the said order shall not in all respects be fully performed and executed within the space of nine months next after the copy thereof shall have been so delivered or left or affixed as aforesaid, then the person or persons therein named, being the master builder, master bricklayer, or master workman, or other person or persons who caused such house or building or bow-window or projection to be erected, shall forfeit the sum of fifty pounds, to be recovered and applied in like manner as the penalties herein-before inflicted for distilling a larger quantity of turpentine together than is by this act allowed, in places not allowed by this act, are herein-before directed to be recovered and applied, and so *toties quoties* for every nine months that such defects and irregularities shall continue, and such house or other building or bow-window or projection shall remain built otherwise than conformable to the directions in such order contained.

Irregularity to be reformed within nine months on pain of 50l. penalty.

XCIV. And whereas several informations may have been commenced before the said mayor of London and justices of the peace for recovering penalties or forfeitures incurred by the said Act made in the twelfth year of his present Majesty's reign, and the same or some of them may be still depending before the said mayor and justices out of session, and other such informations may be depending before the justices in the said respective quarter sessions of the peace, by appeal or otherwise; be it enacted by the authority aforesaid, that the several defendants in all and every such informations shall be and are by the authority of this act discharged, acquitted, and indemnified from and against all such informations; and the said mayor and justices shall acquit and discharge them of and from the same accordingly.

Prosecutions depending before justices of the peace discharged.

XCV. And be it further enacted by the authority aforesaid, that no order which shall be made by the mayor of the city of London for the time being, or by any justice or justices of the peace, by virtue of or under this act, or any other proceeding to be had touching the conviction of any offender or offenders against this act, shall be removed or removeable by certiorari or any other writ or process whatsoever into any of His Majesty's courts of record at Westminster.

No order of the mayor or justice, or other proceeding, to be removed by certiorari.

XCVI. And be it further enacted by the authority aforesaid, that if any person or persons think him, her, or themselves aggrieved by any conviction, commitment, distress, order, or judgment of the mayor of the city of London for the time being, or of any justice or justices of the peace, made out of sessions by virtue of this act, such person or persons may appeal to the justices of the peace at their general quarter sessions of the peace to be holden in and for the city of London and liberties thereof, the counties of Middlesex or Surrey, the city and liberty of Westminster, or the liberties of His Majesty's Tower of London, (as the case may be,) which shall be holden next after such conviction, commitment, distress, order, or judgment, who shall proceed to hear and examine on oath into the causes and matters of such appeal, (which oath or oaths they are hereby empowered to administer,) and shall determine the same, and award such costs to the party or parties appealing or appealed against as they shall think proper, and the order, judgment, and determination of the said justices in their respective sessions shall be binding and conclusive to all parties.

Appeal may be made to the justices at the quarter sessions.

XCVII. Provided always, and be it further enacted by the authority aforesaid, that the person or persons so intending to appeal shall immediately after such conviction, commitment, distress, order, or judgment, or within two days afterwards, enter into a recognizance to the party or parties appealed against, before such justice or justices of the peace, with two sufficient securities, conditioned to try such appeal, and to abide the order of and pay to the party or parties appealed against such costs (if any) as shall be awarded against him, her, or them by the sessions respectively.

Proviso.

XCVIII. And be it further enacted by the authority aforesaid, that the parishioners and inhabitants of the parish, precinct, or place where any offence against this act shall be committed shall be allowed to be competent witnesses on the trial, or otherwise, in any action, bill, plaint, or information in any of the said courts of record, or at or upon the hearing and determination of any information before the mayor of London, or other justice of the peace, for or concerning any offence or offences against this present act, notwithstanding his, her, or their being a parishioner or parishioners, inhabitant or inhabitants, in such parish, precinct, or place.

Parishioners may be witnesses.

XCIX. Provided always, that no action or prosecution shall be brought or commenced

Limitation of actions for penalties.

against any person or persons for any penalty or forfeiture inflicted or incurred by this act unless the same shall be commenced within six calendar months next after such forfeiture shall have been incurred.

Limitation of actions against persons acting under the act.

General issue.

C. And be it further enacted by the authority aforesaid, that no action or suit shall be commenced against any person or persons for any thing done in pursuance of this act until twenty-one days after notice in writing of an intention to bring such action or suit has been given to the person or persons against whom such action or suit shall be brought, nor after the expiration of three calendar months next after the fact committed; and every such action or suit, the cause whereof shall arise within the said city of London or the liberties thereof, shall be laid and tried in the said city of London and not elsewhere, and every such action or suit, the cause whereof shall arise in any part of the limits aforesaid out of the said city of London and liberties thereof, shall be laid and tried in the county of Middlesex, and not elsewhere; and the defendant or defendants in every such action or suit may plead the general issue, and give this act and the special matter in evidence, at any trial or trials to be had thereupon, and that the matter or thing for which such action or suit is brought was done in pursuance and by the authority of this act; and if the said matter or thing appear to have been so done, or if it appear that such action or suit was brought before the expiration of twenty-one days after such notice given as aforesaid, or that sufficient satisfaction was made or tendered before such action was brought, or if any such action or suit be not commenced within the time herein for that purpose limited, or be laid in any other county or place than as aforesaid, then the jury in every such action or suit shall find for the defendant or defendants therein; and if a verdict be found for the defendant or defendants, or if the plaintiff or plaintiffs in any such action or suit become nonsuited, or discontinue or suffer a discontinuance of any such action or suit, or if in any such action or suit judgment be given for the defendant or defendants therein on demurrer or by default or otherwise, then and in any of the cases aforesaid the defendant or defendants shall have judgment to recover treble costs of suit, and shall have such remedy for recovering the same as any defendant or defendants may have for costs in other cases by law.

Repealing former acts so far as respects party-walls, regulating of buildings, preventing mischiefs by fire, &c.

19 Car. II. c. 3.

6 Anne, c. 31.

7 Anne, c. 17.

11 G. 1. c. 28.

33 G. II. c. 30.

4 G. III. c. 14.

6 G. III. c. 27.

CI. And be it further enacted, that from and after the said twenty-fourth day of June, one thousand seven hundred and seventy-four, the said act passed in the twelfth year of the reign of his present Majesty, intituled "An act for the better regulation of buildings and party-walls within the cities of London and Westminster, and the liberties thereof, and other the parishes, precincts, and places in the weekly bills of mortality, the parishes of Saint Mary-le-bone and Paddington, Saint Pancras, and Saint Luke at Chelsea, in the county of Middlesex; and for the better preventing of mischiefs by fire within the said cities, liberties, parishes, precincts, and places; and for amending and reducing the laws relating thereto into one act; and for other purposes," shall be and the same is hereby repealed; but nevertheless so much of an act made in the nineteenth year of the reign of his late Majesty King Charles the Second, intituled "An act for rebuilding the city of London," as relates to the regulating buildings and party-walls; and an act made in the sixth year of the reign of her late Majesty Queen Anne, intituled "An act for the better preventing mischiefs that may happen by fire;" also an act made in the seventh year of the reign of her said late Majesty, intituled "An act for making more effectual an act made in the sixth year of Her Majesty's reign, for the better preventing of mischiefs that may happen by fire;" also so much of an act made in the eleventh year of the reign of his late Majesty King George the First, intituled "An act for the better regulating of buildings, and to prevent mischiefs that may happen by fire, within the weekly bills of mortality, and other places therein mentioned," as relates to regulating buildings and party-walls; also so much of an act made in the thirty-third year of the reign of his late Majesty King George the Second, (intituled "An act for widening certain streets, lanes, and passages within the city of London and liberties thereof, and for opening certain new streets and ways within the same, and for other purposes therein mentioned,") as relates to the regulating of buildings and party-walls, and preventing mischiefs that may happen by fire; also so much of an act made in the fourth year of the reign of his present Majesty (intituled "An act for the better regulating of buildings, and to prevent mischiefs that may happen by fire, within the weekly bills of mortality, and other places therein mentioned,) as relates to the regulating of buildings and party-walls, and preventing mischiefs happening by fire; also so much of an act made in the sixth year of his present Majesty's reign, (intituled "An act to explain, amend, and render more effectual the powers of an act made in the thirty-third year of the reign of his late Majesty, intituled 'An act for widening certain streets, lanes, and passages within the city of London and liberties thereof, and for opening certain new streets and ways within the same, and for other purposes therein mentioned,'") as relates to the regulating of buildings and party-walls; also so much of another act made in the said sixth year of his present Majesty's reign

6 G. III. c. 37.

(intituled "An act to explain, amend, and render more effectual an act made in the fourth year of his present Majesty's reign for the better regulating of buildings, and to prevent mischiefs that may happen by fire, within the weekly bills of mortality, and other places therein mentioned,") as relates to the regulating of buildings and party-walls, and preventing mischiefs that may happen by fire, shall be and continue repealed.

Public act.

CII. And be it further enacted by the authority aforesaid, that this act shall be deemed and taken to be a public act, and shall be judicially taken notice of as such by all judges, justices, and other persons whomsoever, without specially pleading the same.

We here think it right to reprint another Act of Parliament, which has lately come into operation, and which, as it subjects builders to penalties for deviating from the method therein prescribed for building flues, is to them, as well as to the architect, of considerable importance. It is the 3 & 4 Vict. c. 85., being intituled

An Act for the regulation of chimney-sweepers and chimneys.

4 & 5 W. IV. c. 35.

Continuance of 4 & 5 W. IV. c. 35.

Whereas an act was passed in the fifth year of the reign of his late Majesty, intituled "An Act for the better regulation of chimney-sweepers and their apprentices, and for the safer construction of chimneys and flues," to continue in force until the first day of January in the year one thousand eight hundred and forty, and from thence until the end of the then next session of Parliament; be it enacted by the Queen's most excellent Majesty, by and with the advice and consent of the lords spiritual and temporal, and commons, in this present parliament assembled, and by the authority of the same, that the said act shall continue and remain in full force until the first day of July in the year one thousand eight hundred and forty-two.

Penalty for compelling or allowing children to climb chimneys.

II. And be it enacted, that from and after the first day of July in the year one thousand eight hundred and forty-two, any person who shall compel or knowingly allow any child or young person under the age of twenty-one years to ascend or descend a chimney, or enter a flue, for the purpose of sweeping, cleaning, or coring the same, or for extinguishing fire therein, shall be liable to a penalty not more than ten pounds or less than five pounds.

No child under sixteen years to be apprenticed to a chimney-sweeper.

III. And be it enacted, that from and after the passing of this act it shall not be lawful to apprentice to any person using the trade or business of a chimney-sweeper any child under the age of sixteen years, and that every indenture of such apprenticeship which may be entered into after such date shall be null and void.

Apprentices may apply to be discharged.

IV. And be it enacted, that upon the application of any child apprenticed to any person using the trade or business of a chimney-sweeper, at any time after the first day of July one thousand eight hundred and forty-one, and previously to the first day of July one thousand eight hundred and forty-two, to any justice of the peace having jurisdiction where the master or mistress of such child shall reside, it shall be lawful for such justice to summon such master or mistress to appear, at a reasonable time to be named in the summons, not being sooner than seven days from the time of granting the summons, before any two justices having jurisdiction as aforesaid; and upon proof made upon oath, to the satisfaction of the justices by whom the case shall be heard, that such apprentice is desirous of being discharged from his or her apprenticeship, it shall be lawful for such justices forthwith to discharge such apprentice by warrant under their hands and seals, for which warrant no fees shall be paid; and no writ of certiorari or other process shall issue to remove any proceedings under this enactment into any of Her Majesty's superior courts of record in England or Ireland, or into the court of session in Scotland.

Indentures of children under sixteen years to cease after 1st July, 1842.

V. And be it enacted, that from and after the first day of July one thousand eight hundred and forty-two all existing indentures of apprenticeship to the trade or business of a chimney-sweeper of any child who shall then be under the age of sixteen years shall be null and void.

Regulating construction of chimneys.

VI. And whereas it is expedient, for the better security from accidents by fire or otherwise, the improved construction of chimneys and flues provided by the said act be continued; be it enacted, that all withs and partitions between any chimney or flue which at any time after the passing of this act shall be built or rebuilt shall be of brick or stone, and at least equal to half a brick in thickness; and every breast-back and with or partition of any chimney or flue hereafter to be built or rebuilt shall be built of sound materials, and the joints of the work well filled in with good mortar or cement, and rendered or stuccoed within; and also that every chimney or flue hereafter to be built or rebuilt in any wall, or of greater length than four feet out of the wall, not being a circular chimney or flue twelve inches in diameter, shall be in every section of the same not less than fourteen inches by nine inches; and no chimney or flue shall be constructed with any angle therein which shall be less obtuse than an angle of one hundred and twenty degrees, except as is herein-after excepted; and every salient or projecting angle in any chimney or flue shall be rounded off four inches at the least, upon pain of forfeiture, by every master builder or other master workman who shall make or cause to be made such chimney or flue, of any sum of not less than ten pounds nor exceeding fifty pounds: provided nevertheless, that notwithstanding this act chimneys or flues may be built at angles with each other of ninety degrees and more, such chimneys or flues having therein proper doors or openings not less than six inches square.

Before whom convictions may be had.

Penalties how to be levied and applied.

VII. And be it enacted, that all convictions for penalties for any offence against this act may be had before two or more justices of the peace acting for the county, riding, city, borough, division, or place where the offence shall happen, or before the sheriff or stewart of any county or stewartry in Scotland; and such penalties, and the costs and charges attending the recovery thereof, shall be levied by distress and sale of the goods and chattels of the offender or person liable or ordered to pay the same respectively, by warrant under the hands and seals of two or more of the said justices, or under the hand of any such sheriff or stewart, rendering the overplus of such distress and sale (if any) to the party or parties, after deducting the charge of making the same, which warrant such justices or sheriffs or stewarts are hereby empowered and required to grant, upon conviction of the offender by confession, or oath of one or more credible witness or witnesses; and the penalties, costs, and charges, when so levied, shall be paid, the one half to the informer, and the other half to the overseers or managers of the poor of the parish, township, or place where the offender shall dwell and inhabit, to be by such overseers or managers applied in aid of the rate or assessment raised for the relief of the poor of such parish, township, or place, and in Scotland, in parishes where there shall be no assessment for the relief of the poor, as the said managers shall direct, or to Her Majesty in case there shall be no such overseer or manager.

In default of payment of penalty the parties convicted to be sent to prison.

VIII. And be it enacted, that the justices of the peace or sheriffs or stewarts by whom any person shall be convicted and adjudged to pay any sum of money for any offence against this act may adjudge that such person shall pay the same, together with costs, either immediately or within such period as the said justices shall think fit; and that in default of payment at the time appointed such person shall be imprisoned in the common gaol or house of correction (with or without hard labour), as to the said justices or sheriffs or stewarts shall seem meet, for any time not exceeding two calendar months; the commitment to be determinable upon payment of the amount of the penalty and costs.

Inhabitants not incompetent witnesses by reason of paying rates.

IX. And be it enacted, that no inhabitant of any parish, township, or place shall be deemed an incompetent witness in any suit, action, information, complaint, appeal, prosecution, or proceeding, to be had, made, prosecuted, or carried on under the authority of this act, for any offence committed within such parish, township, or place, by reason of such person being rated or assessed to or liable to be rated or assessed to, or being otherwise interested in the rates or assessments of any such parish, township, or place.

Distress not to be deemed unlawful for want of form.

X. And be it enacted, that where any distress shall be made for any sum or sums of money to be levied by virtue of this act the distress itself shall not be deemed unlawful, nor the party or parties making the same be deemed a trespasser or trespassers, on account of any default or want of form in any proceedings relating thereto, nor shall the party or parties distraining be deemed a trespasser or trespassers from the beginning, on account of any irregularity which shall be afterwards done by the party or parties distraining, but the person or persons aggrieved by such irregularity may recover full satisfaction for the special damage in an action on the case, to be brought in some of the courts of record at Westminster or Dublin, or by action raised or complaint preferred in the court of session in Scotland: provided always, that no plaintiff or plaintiffs shall recover in any action for any such irregularity, trespass, or wrongful proceeding, if tender of sufficient amends for any such special damage shall be made by or on behalf of the party or parties who shall have committed or caused to have been committed any such irregularity or wrongful proceeding before such action or complaint brought; and in case no such tender shall have been made, it shall be lawful for the defendant or defendants in any such action, by leave of the court where such action shall depend, at any time before issue joined, to pay into court such sum of money as he or they shall see fit, whereupon such proceedings or orders and judgments shall be had, made, and given in and by such court as in other actions where the defendant is allowed to pay money into court.

Tender of amends.

Appeal.

XI. And be it enacted, that any person who shall think himself or herself aggrieved by any conviction by any justice or justices of the peace under this act may appeal to the next court of general or quarter sessions of the peace which shall be holden not less than twelve days after the day of such conviction for the county, stewartry, riding, city, borough, division, or place wherein the cause of complaint shall have arisen; provided that such person shall give to the complainant a notice in writing of such appeal, and of the cause and matter thereof, within three days after such conviction, and seven clear days at the least before such session, and shall also either remain in custody until the session, or enter into a recognizance, with two sufficient sureties, before a justice of the peace, conditioned personally to appear at the said session of the peace, and to try such appeal, and to abide the judgment of the court thereupon, and to pay such costs as shall be by the court awarded; and upon such notice being given, and such recognizance being entered into, the justice before whom the same shall be entered into shall liberate such person, if in custody, and the court at such session shall hear and determine the matter of the appeal, and shall make such order therein, with or without costs to either party, as to the court shall seem meet, and in case of the dismissal of the appeal or affirmance of the conviction shall order and adjudge the offender to be punished according to the conviction, and to pay such costs as shall be awarded, and shall, if necessary, issue process for enforcing such judgment; and all judgments, determinations, and proceedings of such justices not appealed from as aforesaid, and of such sheriff or stewart or quarter sessions, shall be final, and not subject to review by any process of law or court whatever, any law or usage to the contrary notwithstanding.

XII. And be it enacted, that no conviction or adjudication made on appeal therefrom shall be quashed for want of form, or be removed by certiorari or otherwise into any of Her Majesty's superior courts of record; and no warrant of commitment shall be held void by reason of any defect therein, provided it be therein alleged that the party has been convicted, and there be a good and valid conviction to sustain the same.

Conviction not to be quashed for want of form.

XIII. And be it enacted, that this act may be amended or repealed by any act to be passed in this session of parliament.

Act may be amended, &c. this session.

The following are the names of the persons in London who have long been established by the promoters of this bill to work the machine: —

Joseph Glass, 2. Moor Lane, Fore Street, Cripplegate.
Robert Day, 21. Newton Street, High Holborn.
Edward Raven, 64. Lant Street, Borough.
Thomas Peacock, Chester Mews North, Chester Street, Grosvenor Place.

The person whose name stands first having been a bricklayer all his life, and being also the inventor of the machine now sanctioned by parliament, may perhaps be safely consulted by persons whose chimneys present any difficulties, and whose prudence may induce them to wish for an experienced workman.

PRICES OF MACHINERY.

The following is a list of the prices of the machines sold by Glass for sweeping chimneys. The machine, of whatever length, is supplied with a proper-sized brush, chimney-cloth and slide, and case complete, with full directions: —

	£	s.	d.		£	s.	d.
30 feet in length	2	13	0	60 feet in length	4	0	0
40 —	3	2	0	70 —	4	9	0
50 —	3	11	0	80 —	4	18	0

II. — DILAPIDATIONS.

The architect, in the course of his practice, is frequently called upon, and he must undertake the task, however uncongenial to his feelings, to ascertain the extent of neglect of a tenant in keeping his premises in proper order according to the covenants of the lease or agreement under which he holds the property. The owner of a tenement let to any person has a right to expect that it shall be delivered up to him, at the expiration of the term, in as good condition as the wear and tear of the time will permit; and the tenant is bound to make good what by his neglect or accident may have injured the premises. If the tenant fails in this, not only upon what was originally demised, but upon what may have been erected after he begins his occupation, he is bound to pay to the landlord a sum equal to what will restore the premises.

The general rule for determining what injuries are considered dilapidations, is to ascertain what is *fair wear* without accident, for such is not dilapidation. Injury by accident is that which happens suddenly, and perceptibly differing from wear, which occurs only by lengthened use. Thus the nosing of a step worn away is not a dilapidation; but if such be broken away, instead of worn, it is a dilapidation. It may be said that accident is defined here with too much latitude, inasmuch as it takes account of that which occurs without apparent reason at any particular time; but we use the term in common language, and may cite as an example, that if the timbers of a floor decay, the floor will yield, even without a load upon it. When accident occurs, such alone does not limit the extent of the dilapidation, but also such injuries to the building as follow in its train. Thus, if the weather-boarding of a building decay from age, so long as the covering be complete and entire, it is no dilapidation; but if broken in any part, that is a dilapidation; and if from want of reparation any of the internal parts of the building be injured, such injury is a dilapidation: so if timber or timbers belonging to any part of a house merely decay, if it or they be still sufficient for the support of the house, no dilapidation can be chargeable; but if such timber or timbers give way, they must be replaced, and all parts made good which suffered by their failure. According to Woodfall (*Landlord and Tenant*), "waste may be done in houses by pulling them down or suffering them to be uncovered, whereby the rafters and other timbers of the house become rotten; but the bare suffering them to be uncovered, without rotting the timber, is not waste: so if a house be uncovered when the tenant cometh in, it is no waste in the tenant to suffer the same to fall down." In external covering, however, it seems that decay arising from inattention to it is dilapidation, even though no accident be the cause. It is always considered that though painting neglected is not itself a dilapidation, yet where decay arises from it, it is one.

Broken glass is not considered a dilapidation, unless there be more than one crack in the pane. Some, however, contend that while the glass is sufficiently entire to exclude the wind and weather, no waste is assignable. Generally it seems then to be the rule, that where accident occurs, it is a dilapidation.

Whatever the tenant has power to remove during the term cannot be chargeable with dilapidations. Upon this point the old rule is, that whatever is *fixed* to the freehold cannot be removed by the tenant: thus a lessee may erect barns or sheds or any building upon wooden or stone or other blocks laid on the surface of the ground, and take them down if he please without substituting anything in their place; but if the barns are fixed into the ground, they immediately become the property of the lessor. There seems, however, to be an exception in respect of buildings erected for the purposes of trade: hence not only coppers and ovens may be taken away, but workshops and the like erected by the tenant for his particular trade. This exception seems at first to have applied only to wooden buildings; but Lord Kenyon held that a brick chimney would prevent a tenant from removing a building, and decided that its being on a brick foundation would not do it. Though this opinion was not held by Lord Ellenborough, yet it was not because the buildings were of brick, but because they were erected for the purposes of agriculture, and not of trade. These matters, however, are not in the province of the architect. It is to be remembered, in all cases, that a lessee is bound to leave the premises in as good condition, after the removal of fixtures or improvements, as though they had never existed: thus, if a marble be substituted for a wooden chimney-piece, when the former is removed, the latter, or one of equal value, must be replaced. If a partition be put up and taken away, all damages to the adjacent work must be repaired.

III. — COMPOUND INTEREST AND ANNUITY TABLES.

In a previous part of this work (797, *et seq.*) we have touched on the nature of compound interest and annuities; and as the architect is often called on to value property, we have thought it right to add some practical observations on the subject, and a set of Tables for the ready calculation of such matters, which we shall here explain.

TABLE FIRST contains the amount of 1*l.* put out to accumulate at compound interest for any number of years up to 100, at the several rates of 3, 4, 5, 6, 7, and 8 per cent. The amount of any other sum is found by multiplying the amount of 1*l.* found in the table at the given rate per cent., and for the given time, by the proposed sum.

Example.

Required the amount of 755*l.* in 51 years, at 5 per cent.

Amount of 1*l.* for 51 years at 5 per cent. is - - - -	12·040769
Given sum - - - - - - - - - -	755
	£9080·780595

or 9090*l.* 15*s.* 7$\frac{3}{10}$*d.*

TABLE SECOND contains the present value of 1*l.* payable at the end of any number of years up to 100. The present value of any given sum payable at the expiration of any number of years is found by multiplying the present value of 1*l.* for the given number of years, at the proposed rate per cent., by the given sum or principal.

Example.

Required the present value of 9090*l.* payable 51 years hence, compound interest being allowed at 5 per cent.

By the table, the present value of 1*l.* payable at the expiration of 51 years at 5 per cent. is	·083051
Given principal	9080
	£754·923590

or 754*l.* 18*s.* $5\frac{6}{10}$*d.*

TABLE THIRD contains the amount of an annuity of 1*l.* for any number of years, and is thus used. Take out the amount of 1*l.* answering to the given time and rate of interest: this multiplied by the given annuity will be the required amount.

Example.

Required the amount of an annuity of 27*l.* in 21 years, at 5 per cent. compound interest.

Annuity of 1*l.* in 21 years at 5 per cent.	35·719251
Annuity given	27
	£964·419777

or 964*l.* 8*s.* $3\frac{7}{10}$*d.*

TABLE FOURTH shows the present value of an annuity of 1*l.* for any number of years, at 3, 4, 5, 6, 7, and 8 per cent., and is used as follows: —

First, when the annuity commences immediately. Multiply the tabular number answering to the given years and rate of interest by the given annuity, and the product will be the value required.

Example.

Required the present value of an annuity of 45*l.*, which is to continue 48 years, at the rate of 5 per cent.

Under 5 and opposite to 48 years is (years' purchase)	18·077157
Annuity given	45
	£813·472065

or 813*l.* 9*s.* $5\frac{3}{10}$*d.*

Second, when the annuity does not commence till after a certain number of years. Multiply the difference between the tabular numbers answering to the time of commencement and end, at the proposed rate of interest, by the given annuity, the product will be the present value required.

Example.

An annuity of 40*l.* is to commence 20 years hence, and is to continue 30 years; required its present value, the rate of interest being 4 per cent.

Under 4 per cent. and opposite to 20 is	13·590326
Under 4 per cent. and opposite to 50 (20 + 30) is	21·482184
Difference	7·891858
Annuity given	40
	£315·674320

or 315*l.* 13*s.* $5\frac{8}{10}$*d.*

TABLE FIFTH contains the annuity which 1*l.* will purchase, compound interest being allowed. The manner of using this table is obvious, from what has been said relative to the preceding tables.

Example.

What annuity for 10 years will 500*l.* purchase, the rate of interest being 5 per cent.?

Under 5 and opposite to 10 is	·129504
Principal given	500
	£64·752000

or 64*l.* 15*s.* $0\frac{5}{10}$*d.*

Tables Sixth, Seventh, and Eighth are for finding the value of annuities on single and joint lives, and were constructed by Simpson, on the London bills of mortality.

To find the value of an annuity for a single life, at a proposed rate of interest, within the limits of the table, take from Table VI. the number answering to the given age and proposed rate of interest, which multiplied by the given annuity, the product will be the value required.

Example.

What is the value of an annuity of 50*l.* upon a single life aged 40 years, according to the London bills of mortality, the rate of interest being 4 per cent.?

The value of an annuity of 1*l.* for 40 years at 4 per cent. is	11·5
Annuity	50
Value	£575

To find the value of an annuity for two joint lives, multiply the number in Table VII. answering to the given ages, and at the proposed rate of interest, by the given annuity, and the product will be the required value.

Example.

What is the value of an annuity of 60*l.* for two joint lives, the one being 30 and the other 40 years, interest at 4 per cent.?

The number answering to 30 and 40 years at 4 per cent. is	8·8
Annuity	60
Value	£528·0

To find the value of an annuity for the longest of two given lives, proceed as directed in the case immediately preceding, but using Table VIII., and the product will be the value.

Example.

What is the value of an annuity of 60*l.* for the longest of two lives, the one being 30 and the other 40 years, interest at 4 per cent.?

The tabular number answering at 4 per cent. is	15·9
Annuity	60
Present value	£954·0

The five first tables which follow are printed from those of Smart; the remainder are from Simpson.

The calculations involving the valuation of annuities on lives are not very frequently imposed on the architect, but it is absolutely necessary he should be capable of performing them, as in the case of valuations of leases upon lives, which sometimes occur to him. The public think that the actuaries of life offices in such cases are the only persons capable of affording information on those subjects; but if they knew as much as we do of the absolute want of mathematical knowledge of seven eighths of these attachés, they would pause before consulting them. There are some few, however, of this class, who in point of knowledge of the subject in question dignify the offices they hold, among whom none can be placed in every attainment of the highest rank superior to Mr. Galloway, the present actuary of the Amicable office. It cannot be supposed that this observation is made from jealousy of the parties, inasmuch as their pursuits are so widely different from those which we follow, that clashing with them would be next to an impossibility.

THE FIRST TABLE OF COMPOUND INTEREST.

The Amount of One Pound in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
½	1·014889	1·019803	1·024695	1·029563	1·034408	1·039230
1	1·030000	1·040000	1·050000	1·060000	1·070000	1·080000
1½	1·045335	1·060596	1·075929	1·091336	1·106816	1·122368
2	1·060900	1·081600	1·102500	1·123600	1·144900	1·166400
2½	1·076695	1·103019	1·129726	1·156817	1·184293	1·212158
3	1·092727	1·124864	1·157625	1·191016	1·225043	1·259712
3½	1·108996	1·147140	1·186212	1·226226	1·267194	1·309131
4	1·125508	1·169858	1·215506	1·262476	1·310796	1·360488
4½	1·142266	1·193026	1·245523	1·299799	1·355897	1·413861
5	1·159274	1·216652	1.276281	1·338225	1·402551	1·469328
5½	1·176534	1·240747	1·307799	1·377787	1·450810	1·526970
6	1·194052	1·265319	1·340095	1·418519	1·500730	1·586874
6½	1·211830	1·290377	1·373189	1·460454	1·552367	1·649128
7	1·229873	1·315931	1·407100	1·503630	1·605781	1·713824
7½	1·248185	1·341992	1·441848	1·548082	1·661033	1·781058
8	1·266770	1·368569	1·477455	1·593848	1·718186	1·850930
8½	1·285631	1·395672	1·513941	1·640967	1·777305	1·923543
9	1·304773	1·423311	1·551328	1·689478	1·838459	1·999004
9½	1·324200	1·451498	1·589638	1·739425	1·901717	2·077426
10	1·343916	1·480244	1·628894	1·790847	1·967151	2.158925
10½	1.363926	1·509558	1·669120	1·843790	2·034837	2·243620
11	1.384233	1·539454	1·710339	1·898298	2·104851	2·331639
11½	1·404843	1·569941	1·752576	1·954417	2·177275	2·423110
12	1·425760	1·601032	1·795856	2·012196	2·252191	2·518170
12½	1·446989	1·632738	1·840205	2·071683	2·329685	2·616959
13	1·468533	1·665073	1·885649	2·132928	2·409845	2·719623
13½	1·490398	1·698048	1·932215	2·195984	2·492763	2·826315
14	1·512589	1·731676	1·979931	2·260903	2·578534	2·937193
14½	1·535110	1·765970	2·028826	2·327743	2·667256	3·052421
15	1·557967	1·800943	2·078928	2·396558	2·759031	3·172169
15½	1·581164	1·836609	2·130267	2·467407	2·853964	3·296614
16	1·604706	1·872981	2·182874	2·540351	2·952163	3·425942
16½	1·628599	1·910073	2·236780	2·615452	3·053741	3·560344
17	1·652847	1·947900	2·292018	2.692772	3·158815	3·700018
17½	1·677457	1·986476	2·348619	2·772379	3·267503	3·845171
18	1·702433	2·025816	2·406619	2·854339	3·379932	3·996019
18½	1·727780	2·065935	2·466050	2·938722	3·496229	4·152785
19	1·753506	2·106849	2·526950	3·025599	3·616527	4·315701
19½	1·779614	2·148573	2·589353	3·115045	3·740965	4·485008
20	1·806111	2·191123	2·653297	3·207135	3·869684	4·660957
20½	1·833002	2·234515	2·718821	3·301948	4·002832	4·843808
21	1·860294	2·278768	2·785962	3·399563	4·140562	5·033833
21½	1·887992	2·323896	2·854762	3·500064	4·283031	5·231313
22	1·916103	2·369918	2·925260	3·603537	4·430401	5·436540
22½	1·944632	2·416852	2·997500	3·710068	4·582843	5·649818
23	1·973586	2·464715	3·071523	3·819749	4·740529	5·871463
23½	2·002971	2·513526	3·147375	3·932672	4·903642	6·101804
24	2·032794	2·563304	3·225099	4·048934	5·072366	6·341180
24½	2·063060	2·614067	3·304744	4·168633	5·246897	6·589948
25	2·093777	2·665836	3·386354	4·291870	5·427432	6·848475

THE FIRST TABLE OF COMPOUND INTEREST — *continued.*

The Amount of One Pound in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
25½	2·124952	2·718630	3·469981	4·418751	5·614179	7·117144
26	2·156591	2·772469	3·555672	4·549382	5·807352	7·396353
26½	2·188701	2·827375	3·643480	4·683876	6·007172	7·686515
27	2·221289	2·883368	3·733456	4·822345	6·213867	7·988061
27½	2·254362	2·940470	3·825654	4·964909	6·427674	8·301437
28	2·287927	2·998703	3·920129	5·111686	6·648838	8·627106
28½	2·321992	3·058089	4·016937	5·262803	6·877611	8·965551
29	2·356565	3·118651	4·116135	5·418387	7·114257	9·317274
29½	2·391652	3·180412	4·217783	5·578571	7·359044	9·682796
30	2·427262	3·243397	4·321942	5·743491	7·612255	10·062656
30½	2·463402	3·307629	4·428673	5·913286	7·874177	10·457419
31	2·500080	3·373133	4·538039	6·088100	8·145112	10·867669
31½	2·537304	3·439934	4·650106	6·268083	8·425370	11.294013
32	2·575082	3·508058	4·764941	6·453386	8·715270	11·737083
32½	2·613423	3·577532	4·882612	6·644168	9·015146	12·197534
33	2·652335	3·648381	5·003188	6·840589	9·325339	12·676049
33½	2·691826	3·720633	5·126742	7·042818	9·646206	13·173337
34	2·731905	3·794316	5·253347	7·251025	9·978113	13·690133
34½	2·772581	3·869458	5·383079	7·465387	10·321440	14·227204
35	2·813862	3·946088	5·516015	7·686086	10·676581	14·785344
35½	2·855758	4·024236	5·652233	7·913310	11·043941	15·365380
36	2·898278	4·103932	5·791816	8·147252	11·423942	15·968171
36½	2·941431	4·185206	5·934845	8·388109	11·817017	16·594610
37	2·985226	4·268089	6·081406	8·636087	12·223618	17·245625
37½	3·029674	4·352614	6·231587	8·891395	12·644208	17·922179
38	3·074783	4·438813	6·385477	9·154252	13·079271	18·625275
38½	3·120564	4·526719	6·543167	9·424879	13·529308	19·355954
39	3·167026	4·616365	6·704751	9·703507	13·994820	20·115297
39½	3·214181	4·707788	6·870325	9·990372	14·476354	20·904430
40	3·262037	4·801020	7·039988	10·285717	14·974457	21·724521
40½	3·310606	4·896099	7·213841	10·589794	15·489699	22·576785
41	3·359898	4·993061	7·391988	10·902861	16·022669	23·462483
41½	3·409924	5·091943	7·574533	11·225182	16·573978	24·382927
42	3·460695	5·192783	7·761587	11·557032	17·144256	25·339481
42½	3·512222	5·295621	7·953260	11·898693	17·734157	26·333562
43	3·564516	5·400495	8·149666	12·250454	18·344354	27·366640
43½	3·617589	5·507446	8·350923	12·612615	18·975548	28·440247
44	3·671452	5·616515	8·557150	12·985481	19·628459	29·555971
44½	3·726117	5·727744	8·768469	13·369371	20·303836	30·715466
45	3·781595	5·841175	8·985007	13·764610	21·002451	31·920449
45½	3·837900	5·956853	9·206893	14·171534	21·725105	33·172704
46	3·895043	6·074822	9·434258	14·590487	22·472623	34·474085
46½	3·953037	6·195127	9·667237	15·021826	23·245862	35·826520
47	4·011895	6·317815	9·905971	15·465916	24·045707	37·232012
47½	4·071628	6·442933	10·150599	15·923135	24·873072	38·692642
48	4·132251	6·570528	10·401269	16·393871	25·728906	40·210573
48½	4·193777	6·700650	10·658129	16·878524	26·614187	41·788053
49	4·256219	6·833349	10·921333	17·377504	27·529929	43·427418
49½	4·319590	6·968676	11·191036	17·891235	28·477180	45·131097
50	4·383906	7·106683	11·467399	18·420154	29·457025	46·901612

THE FIRST TABLE OF COMPOUND INTEREST — *continued.*

The Amount of One Pound in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
50½	4·449178	7·247423	11·750588	18·964709	30·470583	48·741585
51	4·515423	7·390950	12·040769	19·525363	31·519016	50·653741
51½	4·582654	7·537320	12·338117	20·102592	32·603524	52·640912
52	4·650885	7·686588	12·642808	20·696885	33·725347	54·706040
52½	4·720133	7·838813	12·955023	21·308747	34·885771	56·852185
53	4·790412	7·994052	13·274948	21·938698	36·086122	59·082524
53½	4·861737	8·152365	13·602774	22·587272	37·327775	61·400360
54	4·934124	8·313814	13·938696	23·255020	38·612150	63·809126
54½	5·007589	8·478460	14·282913	23·942508	39·940719	66·312389
55	5·082148	8·646366	14·635630	24·650321	41·315001	68·913856
55½	5·157817	8·817598	14·997058	25·379059	42·736569	71·617380
56	5·234613	8·992221	15·367412	26·129340	44·207051	74·426964
56½	5·312552	9·170302	15·746911	26·901802	45·728129	77·346770
57	5·391651	9·351910	16·135783	27·697101	47·301545	80·381121
57½	5·471928	9·537114	16·534257	28·515911	48·929098	83·534512
58	5·553400	9·725986	16·942572	29·358927	50·612653	86·811611
58½	5·636086	9·918599	17·360970	30·226865	52·354135	90·217273
59	5·720003	10·115026	17·789700	31·120463	54·155539	93·756540
59½	5·805169	10·315343	18·229018	32·040477	56·018925	97·434655
60	5·891603	10·519627	18·679185	32·987690	57·946426	101·257063
60½	5·979324	10·727957	19·140469	33·962906	59·940249	105·229427
61	6·068351	10 940412	19·613145	34·966952	62·002676	109·357628
61½	6·158703	11·157075	20·097493	36·000680	64·136067	113·647781
62	6·250401	11·378029	20·593802	37·064969	66·342864	118·106239
62½	6·343464	11·603358	21·102367	38·160721	68·625592	122·739604
63	6·437913	11·833150	21·623492	39·288867	70·986864	127·554738
63½	6·533768	12·067492	22·157486	40·450364	73·429383	132·558772
64	6·631051	12·306476	22·704667	41·646199	75·955945	137·759117
64½	6·729781	12·550192	23·265360	42·877386	78·569440	143·163474
65	6·829982	12·798735	23·839900	44·144971	81·272861	148·779846
65½	6·931675	13·052200	24·428628	45·450030	84·069301	154·616552
66	7·034882	13·310684	25·031895	46·793669	86·961961	160·682234
66½	7·139625	13·574288	25·650060	48·177031	89·954152	166·985876
67	7·245928	13·843112	26·283490	49·601290	93·049298	173·536813
67½	7·353814	14·117259	26·932563	51·067653	96·250943	180·344746
68	7·463306	14·396836	27·597664	52·577367	99·562749	187·419758
68½	7·574428	14·681950	28·279191	54·131713	102·988509	194·772326
69	7·687205	14·972709	28·977548	55·732009	106·532142	202·413338
69½	7·801661	15·269228	29·693150	57·379615	110·197704	210·354112
70	7·917821	15·571618	30·426425	59·075930	113·989392	218·606405
70½	8·035711	15·879997	31·177808	60·822392	117·911544	227·182441
71	8·155356	16·194483	31·947746	62·620485	121·968649	236·094918
71½	8·276782	16·515197	32·736698	64·471736	126·165352	245·357036
72	8·400017	16·842262	33·545134	66·377715	130·506455	254·982511
72½	8·525086	17·175804	34·373533	68·340040	134·996926	264·985599
73	8·652017	17·515952	35·222390	70·360378	139·641906	275·381112
73½	8·780839	17·862837	36·092210	72·440442	144·446711	286·184447
74	8·911578	18·216591	36·983510	74·582000	149·416840	297·411601
74½	9·044264	18·577350	37·896821	76·786869	154·557981	309·079203
75	9·178925	18·945254	38·832685	79·056920	159·876019	321·204529

The First Table of Compound Interest — *continued.*

The Amount of One Pound in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
75½	9·315592	19·320444	39·791662	81·394081	165·377040	333·805539
76	9·454293	19·703064	40·774320	83·800336	171·067340	346·900892
76½	9·595059	20·093262	41·781245	86·277726	176·953433	360·509982
77	9·737922	20·491187	42·813036	88·828356	183·042054	374·652963
77½	9·882911	20·896992	43·870307	91·454390	189·340173	389·350781
78	10·030059	21·310834	44·953688	94·158057	195·854998	404·625200
78½	10·179399	21·732872	46·063822	96·941653	202·593985	420·498844
79	10·330961	22·163268	47·201372	99·807541	209·564848	436·995216
79½	10·484781	22·602187	48·367013	102·758152	216·775564	454·138751
80	10·640890	23·049799	49·561441	105·795993	224·234387	471·954834
80½	10·799324	23·506275	50·785364	108·923642	231·949854	490·469851
81	10·960117	23·971791	52·039513	112·143753	239·930794	509·711221
81½	11·123304	24·446526	53·324632	115·459060	248·186343	529·707439
82	11·288920	24·930662	54·641488	118·872378	256·725950	550·488118
82½	11·457003	25·424387	55·990864	122·386604	265·559387	572·084035
83	11·627588	25·927889	57·373563	126·004720	274·696766	594·527168
83½	11·800713	26·441362	58·790407	129·729800	284·148545	617·850757
84	11·976416	26·965004	60·242241	133·565004	293·925540	642·089341
84½	12·154734	27·499017	61·729928	137·513588	304·038943	667·278818
85	12·335708	28·043604	63·254353	141·578904	314·500328	693·456488
85½	12·519376	28·598977	64·816424	145·764403	325·321669	720·661124
86	12·705779	29·165349	66·417071	150·073638	336·515351	748·933008
86½	12·894958	29·742936	68·057245	154·510267	348·094186	778·314013
87	13·086953	30·331963	69·737924	159·078057	360·071425	808·847648
87½	13·281806	30·932654	71·460108	163·780884	372·460779	840·579135
88	13·479561	31·545241	73·224820	168·622740	385·276425	873·555460
88½	13.680261	32·169960	75·033113	173·607737	398·533033	907·825465
89	13·883948	32·807051	76·886061	178·740104	412·245775	943.439897
89½	14·090668	33·456758	78·784769	184·024201	426·430345	980·451503
90	14·300467	34·119333	80·730365	189·464511	441·102979	1018·915089
90½	14·513389	34·795029	82·724007	195·065653	456·280470	1058·887623
91	14·729481	35·484106	84·766883	200·832381	471·980188	1100·428296
91½	14·948790	36·186830	86·860208	206·769592	488·220103	1143·598633
92	15·171365	36·903470	89·005227	212·882324	505·018801	1188·462560
92½	15·397254	37·634303	91·203218	219·175768	522·395510	1235·086523
93	15·626506	38·379609	93·455488	225·655264	540·370117	1283·539564
93½	15·859172	39·139675	95·763379	232·326314	558·963196	1333·893445
94	16.095301	39·914794	98·128263	239·194580	578·196026	1386·222730
94½	16·334947	40·705262	100·551548	246·265893	598·090619	1440·604921
95	16·578160	41·511385	103·034676	253·546254	618·669747	1497·120548
95½	16·824995	42·333473	105·579125	261·041846	639·956963	1555·853315
96	17·075505	43·171841	108·186410	268·759030	661·976630	1616·890192
96½	17·329745	44·026812	110·858082	276·704357	684·753950	1680·321580
97	17·587770	44·898715	113·595730	284·884572	708·314994	1746·241407
97½	17·849637	45·787884	116·400986	293·306618	732·686727	1814·747306
98	18·115403	46·694663	119·275517	301·977646	757·897043	1885·940720
98½	18·385126	47·619400	122·221035	310·905016	783·974797	1959·927091
99	18·658866	48·562450	125·239293	320·096305	810·949836	2036·815978
99½	18·936680	49·524176	128·332087	329·559317	838·853033	2116·721258
100	19·218631	50·504948	131·501257	339·302083	867·716325	2199·761256

THE SECOND TABLE OF COMPOUND INTEREST.

The present Value of One Pound payable at the End of any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
½	·985329	·980580	·975900	·971285	·966736	·962250
1	·970873	·961538	·952380	·943396	·934579	·925925
1½	·956630	·942866	·929428	·916307	·903492	·890972
2	·942595	·924556	·907029	·889996	·873438	·857338
2½	·928767	·906601	·885170	·864440	·844385	·824974
3	·915141	·888996	·863837	·839619	·816297	·793832
3½	·901715	·871732	·843019	·815510	·789144	·763865
4	·888487	·854804	·822702	·792093	·762895	·735029
4½	·875452	·838204	·802875	·769349	·737518	·707282
5	·862608	·821927	·783526	·747258	·712986	·680583
5½	·849953	·805965	·764643	·725801	·689269	·654891
6	·837484	·790314	·746215	·704960	·666342	·630169
6½	·825197	·774967	·728231	·684718	·644177	·606381
7	·813091	·759917	·710681	·665057	·622749	·583490
7½	·801162	·745160	·693553	·645960	·602034	·561463
8	·789409	·730690	·676839	·627412	·582009	·540268
8½	·777828	·716500	·660527	·609396	·562649	·519873
9	·766416	·702586	·644608	·591898	·543933	·500248
9½	·755172	·688942	·629073	·574902	·525840	·481364
10	·744093	·675564	·613913	·558394	·508349	·463193
10½	·733177	·662445	·599117	·542360	·491439	·445708
11	·722421	·649580	·584679	·526787	·475092	·428882
11½	·711822	·636966	·570588	·511661	·459289	·412692
12	·701379	·624597	·556837	·496969	·444011	·397113
12½	·691090	·612467	·543417	·482699	·429242	·382122
13	·680951	·600574	·530321	·468839	·414964	·367697
13½	·670961	·588911	·517540	·455376	·401161	·353817
14	·661117	·577475	·505067	·442300	·387817	·340461
14½	·651418	·566260	·492895	·429600	·374917	·327608
15	·641861	·555264	·481017	·417265	·362446	·315241
15½	·632445	·544481	·469424	·405283	·350389	·303341
16	·623166	·533908	·458111	·393646	·338734	·291890
16½	·614024	·523540	·447071	·382343	·327467	·280871
17	·605016	·513373	·436296	·371364	·316574	·270268
17½	·596140	.503403	·425781	·360701	·306044	·260066
18	·587394	·493628	·415520	·350343	·295863	·250249
18½	·578777	·484042	·405506	·340283	·286022	·240802
19	·570286	·474642	·395733	·330513	·276508	·231712
19½	·561919	·465425	·386196	·321022	·267310	·222965
20	·553675	·456386	·376889	·311804	·258419	·214548
20½	·545552	·447524	·367806	·302851	·249823	·206449
21	·537549	·438833	·358942	·294155	·241513	·198655
21½	·529663	·430311	·350291	·285708	·233479	·191156
22	·521892	·421955	·341849	·277505	·225713	·183940
22½	·514235	·413761	·333611	·269536.	·218205	·176996
23	·506691	·405726	·325571	·261797	·210946	·170315
23½	·499258	·397847	·317725	·254279	·203930	·163885
24	·491933	·390121	·310067	·246978	·197146	·157699
24½	·484716	·382545	·302595	·239886	·190588	·151746
25	·477605	·375116	·295302	·232998	·184249	·146017

The Second Table of Compound Interest — *continued.*

The present Value of One Pound payable at the End of any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
25½	·470598	·367832	·288186	·226308	·178120	·140505
26	·463694	·360689	·281240	·219810	·172195	·135201
26½	·456891	·353684	·274462	·213498	·166467	·130097
27	·450189	·346816	·267848	·207367	·160930	·125186
27½	·443584	·340081	·261393	·201413	·155577	·120461
28	·437076	·333477	·255093	·195630	·150402	·115913
28½	·430664	·327001	·248945	·190012	·145399	·111538
29	·424346	·320651	·242946	·184556	·140562	·107327
29½	·418120	·314424	·237091	·179257	·135887	·103275
30	·411986	·308318	·231377	·174110	·131367	·099377
30½	·405942	·302331	·225801	·169110	·126997	·095625
31	·399987	·296460	·220359	·164254	·122773	·092016
31½	·394119	·290703	·215048	·159538	·118689	·088542
32	·388337	·285057	·209866	·154957	·114741	·085200
32½	·382639	·279522	·204808	·150507	·110924	·081983
33	·377026	·274094	·199872	·146186	·107234	·078888
33½	·371495	·268771	·195055	·141988	·103667	·075910
34	·366044	·263552	·190354	·137911	·100219	·073045
34½	·360674	·258434	·185767	·133951	·096885	·070287
35	·355383	·253415	·181290	·130105	·093662	·067634
35½	·350169	·248494	·176921	·126369	·090547	·065081
36	·345032	·243668	·172657	·122740	·087535	·062624
36½	·339970	·238936	·168496	·119216	·084623	·060260
37	·334982	·234296	·164435	·115793	·081808	·057985
37½	·330068	·229746	·160472	·112468	·079087	·055796
38	·325226	·225285	·156605	·109238	·076456	·053690
38½	·320454	·220910	·152831	·106102	·073913	·051663
39	·315753	·216620	·149147	·103055	·071455	·049713
39½	·311121	·212413	·145553	·100096	·069078	·047836
40	·306556	·208289	·142045	·097222	·066780	·046030
40½	·302059	·204244	·138622	·094430	·064559	·044293
41	·297628	·200277	·135281	·091719	·062411	·042621
41½	·293261	·196388	·132021	·089085	·060335	·041012
42	·288959	·192574	·128839	·086527	·058328	·039464
42½	·284719	·188835	·125734	·084042	·056388	·037974
43	·280542	·185168	·122704	·081629	·054512	·036540
43½	·276427	·181572	·119747	·079285	·052699	·035161
44	·272371	·178046	·116861	·077009	·050946	·033834
44½	·268375	·174588	·114044	·074797	·049251	·032556
45	·264438	·171198	·111296	·072650	·047613	·031327
45½	·260559	·167873	·108614	·070563	·046029	·030145
46	·256736	·164613	·105996	·068537	·044498	·029007
46½	·252970	·161417	·103442	·066569	·043018	·027912
47	·249258	·158282	·100949	·064658	·041587	·026858
47½	·245601	·155208	·098516	·062801	·040204	·025844
48	·241998	·152194	·096142	·060998	·038866	·024869
48½	·238448	·149239	·093825	·059246	·037573	·023930
49	·234950	·146341	·091563	·057545	·036324	·023026
49½	·231503	·143499	·089357	·055893	·035115	·022157
50	·228107	·140712	·087203	·054288	·033947	·021321

THE SECOND TABLE OF COMPOUND INTEREST — *continued.*

The present Value of One Pound payable at the End of any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
50½	·224760	·137980	·085102	·052729	·032818	·020516
51	·221463	·135300	·083051	·051215	·031726	·019741
51½	·218214	·132673	·081049	·049744	·030671	·018996
52	·215012	·130096	·079096	·048316	·029651	·018279
52½	·211858	·127570	·077190	·046929	·028664	·017589
53	·208750	·125093	·075329	·045581	·027711	·016925
53½	·205687	·122663	·073514	·044272	·026789	·016286
54	·202670	·120281	·071742	·043001	·025898	·015671
54½	·199696	·117945	·070013	·041766	·025037	·015080
55	·196767	·115655	·068326	·040567	·024204	·014510
55½	·193880	·113409	·066679	·039402	·023399	·013963
56	·191036	·111207	·065072	·038271	·022620	·013435
56½	·188233	·109047	·063504	·037172	·021868	·012928
57	·185471	·106930	·061974	·036104	·021140	·012440
57½	·182750	·104853	·060480	·035068	·020437	·011971
58	·180069	·102817	·059022	·034061	·019757	·011519
58½	·177428	·100820	·057600	·033083	·019100	·011084
59	·174825	·098862	·056212	·032133	·018465	·010665
59½	·172260	·096942	·054857	·031210	·017851	·010263
60	·169733	·095060	·053535	·030314	·017257	·009875
60½	·167242	·093214	·052245	·029443	·016683	·009503
61	·164789	·091404	·050986	·028598	·016128	·009144
61½	·162371	·089629	·049757	·027777	·015591	·008799
62	·159989	·087888	·048558	·026979	·015073	·008466
62½	·157642	·086181	·047388	·026204	·014571	·008147
63	·155329	·084508	·046246	·025452	·014087	·007839
63½	·153051	·082867	·045131	·024721	·013618	·007548
64	·150805	·081258	·044043	·024011	·013165	·007259
64½	·148593	·079680	·042982	·023322	·012727	·006985
65	·146413	·078132	·041946	·022652	·012304	·006721
65½	·144265	·076615	·040935	·022002	·011894	·006467
66	·142148	·075127	·039949	·021370	·011499	·006223
66½	·140063	·073668	·038986	·020756	·011116	·005988
67	·138008	·072238	·038046	·020160	·010746	·005762
67½	·135983	·070835	·037129	·019581	·010389	·005544
68	·133988	·069459	·036234	·019019	·010043	·005335
68½	·132023	·068110	·035361	·018473	·009709	·005134
69	·130086	·066788	·034509	·017943	·009386	·004940
69½	·128177	·065491	·033677	·017427	·009074	·004753
70	·126297	·064219	·032866	·016927	·008772	·004574
70½	·124444	·062972	·032074	·016441	·008480	·004401
71	·122618	·061749	·031301	·015969	·008198	·004235
71½	·120819	·060550	·030546	·015510	·007926	·004075
72	·119047	·059374	·029810	·015065	·007662	·003921
72½	·117300	·058221	·029092	·014632	·007407	·003773
73	·115579	·057090	·028391	·014212	·007161	·003631
73½	·113884	·055982	·027706	·013804	·006922	·003494
74	·112213	·054895	·027039	·013408	·006692	·003362
74½	·110567	·053828	·026387	·013023	·006470	·003235
75	·108945	·052783	·025751	·012649	·006254	·003113

The Second Table of Compound Interest — *continued.*

The present Value of One Pound payable at the End of any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
75½	·107346	·051758	·025130	·012285	·006046	·002995
76	·105772	·050753	·024525	·011933	·005845	·002882
76½	·104220	·049767	·023934	·011590	·005651	·002773
77	·102691	·048801	·023357	·011257	·005463	·002669
77½	·101184	·047853	·022794	·010934	·005281	·002568
78	·099700	·046924	·022245	·010620	·005105	·002471
78½	·098237	·046013	·021709	·010315	·004935	·002378
79	·096796	·045119	·021185	·010019	·004771	·002288
79½	·095376	·044243	·020675	·009731	·004613	·002201
80	·093977	·043384	·020176	·009452	·004459	·002118
80½	·092598	·042541	·019690	·009180	·004311	·002038
81	·091239	·041715	·019216	·008917	·004167	·001961
81½	·089901	·040905	·018753	·008661	·004029	·001887
82	·088582	·040111	·018301	·008412	·003895	·001816
82½	·087282	·039332	·017860	·008170	·003765	·001747
83	·086002	·038568	·017429	·007936	·003640	·001682
83½	·084740	·037819	·017009	·007708	·003519	·001618
84	·083497	·037085	·016599	·007486	·003402	·001557
84½	·082272	·036364	·016199	·007272	·003289	·001498
85	·081065	·035658	·015809	·007063	·003179	·001442
85½	·079876	·034966	·015428	·006860	·003073	·001387
86	·078704	·034287	·015056	·006663	·002971	·001335
86½	·077549	·033621	·014693	·006472	·002872	·001284
87	·076411	·032968	·014339	·006286	·002777	·001236
87½	·075290	·032328	·013993	·006105	·002684	·001189
88	·074186	·031700	·013656	·005930	·002595	·001144
88½	·073098	·031084	·013327	·005760	·002509	·001101
89	·072025	·030481	·013006	·005594	·002425	·001059
89½	·070968	·029889	·012692	·005434	·002345	·001019
90	·069927	·029308	·012386	·005278	·002267	·000981
90½	·068901	·028739	·012088	·005126	·002191	·000944
91	·067891	·028181	·011797	·004979	·002118	·000908
91½	·066895	·027634	·011512	·004836	·002048	·000874
92	·065913	·027097	·011235	·004697	·001980	·000841
92½	·064946	·026571	·010964	·004562	·001914	·000809
93	·063993	·026055	·010700	·004431	·001850	·000779
93½	·063054	·025549	·010442	·004304	·001789	·000749
94	·062129	·025053	·010190	·004180	·001729	·000721
94½	·061218	·024566	·009945	·004060	·001671	.000694
95	·060320	·024089	·009705	·003944	·001616	·000667
95½	·059435	·023621	·009471	·003830	·001562	·000642
96	·058563	·023163	·009243	·003720	·001510	·000618
96½	·057704	·022713	·009020	·003613	·001460	·000595
97	·056857	·022272	·008803	·003510	·001411	·000572
97½	·056023	·021839	·008590	·003409	·001364	·000551
98	·055201	·021415	·008383	·003311	·001319	·000530
98½	·054391	·020999	·008181	·003216	·001275	·000510
99	·053593	·020592	·007984	·003124	·001233	·000490
99½	·052807	·020192	·007792	·003034	·001192	·000472
100	·052032	·019800	·007604	·002947	·001152	·000454

THE THIRD TABLE OF COMPOUND INTEREST.

The Amount of One Pound per Annum in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
½	·496305	·495097	·493901	·492716	·491543	·490381
1	1·000000	1·000000	1·000000	1·000000	1·000000	1·000000
1½	1·511194	1·514901	1·518596	1·522279	1·525951	1·529611
2	2·030000	2·040000	2·050000	2·060000	2·070000	2·080000
2½	2·556530	2·575497	2·594526	2·613616	2·632768	2·651980
3	3·090900	3·121600	3·152500	3·183600	3·214900	3·246400
3½	3·633226	3·678517	3·724252	3·770433	3·817061	3·864138
4	4·183627	4·246464	4·310125	4·374616	4·439943	4·506112
4½	4·742222	4·825658	4·910465	4·996659	5·084256	5·173270
5	5·309135	5·416322	5·525631	5·637092	5·750739	5·866600
5½	5·884489	6·018684	6·155988	6·296459	6·440154	6·587131
6	6·468409	6·632975	6·801912	6·975318	7·153290	7·335929
6½	7·061024	7·259431	7·463788	7·674246	7·890964	8·114102
7	7·662462	7·898294	8·142008	8·393837	8·654021	8·922803
7½	8·272855	8·549809	8·836977	9·134701	9·443332	9·763230
8	8·892336	9·214226	9·549108	9·897467	10·259802	10·636627
8½	9·521040	9·891801	10·278826	10·682783	11·104365	11·544288
9	10·159106	10·582795	11·026564	11·491315	11·977988	12·487557
9½	10·806671	11·287473	11·792767	12·323750	12·881671	13·467831
10	11·463879	12·006107	12·577892	13·180794	13·816447	14·486562
10½	12·130872	12·738972	13·382406	14·063175	14·783388	15·545258
11	12·807795	13·486351	14·206787	14·971642	15·783599	16·645487
11½	13·494798	14·248531	15·051526	15·906966	16·818225	17·788879
12	14·192029	15·025805	15·917126	16·869941	17·888451	18·977126
12½	14·899642	15·818472	16·804102	17·861384	18·995501	20·211989
13	15·617790	16·626837	17·712982	18·882137	20·140642	21·495296
13½	16·346631	17·451211	18·644307	19·933067	21·325186	22·828948
14	17·086324	18·291911	19·598631	21·015065	22·550487	24·214920
14½	17·837030	19·149260	20·576523	22·129051	23·817949	25·655264
15	18·598913	20·023587	21·578563	23·275969	25·129022	27·152113
15½	19·372141	20·915230	22·605349	24·456794	26·485205	28·707685
16	20·156881	21·824531	23·657491	25·672528	27·888053	30·324283
16½	20·953305	22·751839	24·735616	26·924202	29·339170	32·004300
17	21·761587	23·697512	25·840366	28·212879	30·840217	33·750225
17½	22·581904	24·661913	26·972397	29·539654	32·392912	35·564644
18	23·414435	25·645412	28·132384	30·905652	33·999032	37·450243
18½	24·259361	26·648389	29·321017	32·312033	35·660416	39·409816
19	25·116868	27·671229	30·539003	33·759991	37·378964	41·446263
19½	25·987142	28·714325	31·787068	35·250755	39·156645	43·562601
20	26·870374	29·778078	33·065954	36·785591	40·995492	45·761964
20½	27·766756	30·862898	34·376421	38·365801	42·897610	48·047609
21	28·676485	31·969201	35·719251	39·992726	44·865176	50·422921
21½	29·599759	33·097414	37·095243	41·667749	46·900443	52·891418
22	30·536780	34·247969	38·505214	43·392290	49·005739	55·456755
22½	31·487752	35·421310	39·950005	45·167814	51·188474	58·122731
23	32·452883	36·617888	41·430475	46·995827	53·436140	60·893295
23½	33·432385	37·838163	42·947505	48·877882	55·766317	63·772550
24	34·426470	39·082604	44·501998	50·815577	58·176670	66·764759
24½	35·435356	40·351689	46·094880	52·810555	60·669959	69·874354
25	36·459264	41·645908	47·727098	54·864512	63·249037	73·105939

The Third Table of Compound Interest — *continued.*

The Amount of One Pound per Annum in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
25½	37·498417	42·965757	49·399624	56·979189	65·916856	76·464302
26	38·553042	44·311744	51·113453	59·156382	68·676470	79·954415
26½	39·623369	45·684387	52·869605	61·397940	71·531036	83·581446
27	40·709633	47·084214	54·669126	63·705765	74·483823	87·350768
27½	41·812070	48·511763	56·513086	66·081817	77·538209	91·267962
28	42·930922	49·967582	58·402582	68·528111	80·697690	95·338829
28½	44·066433	51·452233	60·338740	71·046726	83·965884	99·569399
29	45·218850	52·966286	62·322711	73·639798	87·346529	103·965936
29½	46·388425	54·510323	64·355677	76·309529	90·843495	108·534951
30	47·575415	56·084937	66·438847	79·058186	94·460786	113·283211
30½	48·780078	57·690735	68·573461	81·888101	98·202540	118·217747
31	50·002678	59·328335	70·760789	84·801677	102·073041	123·345868
31½	51·243481	60·998365	73·002134	87·801387	106·076718	128·675167
32	52·502758	62·701468	75·298829	90·889778	110·218154	134·213537
32½	53·780785	64·438300	77·652241	94·069470	114·502088	139·969180
33	55·077841	66·209527	80·063770	97·343164	118·933425	145·950620
33½	56·394209	68·015832	82·534853	100·713639	123·517234	152·166715
34	57·730176	69·857908	85·066959	104·183754	128·258764	158·626670
34½	59·086035	71·736465	87·661596	107·756457	133·163441	165·340052
35	60·462081	73·652224	90·320307	111·434779	138·236878	172·316803
35½	61·858616	75·605923	93·044675	115·221844	143·484882	179·567256
36	63·275944	77·598313	95·836322	119·120866	148·913459	187·102147
36½	64·714374	79·630160	98·696909	123·135155	154·528824	194·932637
37	66·174222	81·702246	101·628138	127·268118	160·337402	203·070319
37½	67·655806	83·815367	104·631755	131·523264	166·345841	211·527248
38	69·159449	85·970336	107·709545	135·904205	172·561020	220·315945
38½	70·685480	88·167982	110·863342	140·414660	178·990050	229·449428
39	72·234232	90·409149	114·095023	145·058458	185·640291	238·941221
39½	73·806044	92·694701	117·406510	149·839540	192·519354	248·805382
40	75·401259	95·025515	120·799774	154·761965	199·635111	259·056518
40½	77·020226	97·402489	124·276835	159·829912	206·995708	269·709812
41	78·663297	99·826536	127·839762	165·047683	214·609569	280·781040
41½	80·330832	102·298588	131·490677	170·419707	222·485408	292·286597
42	82·023196	104·819597	135·231751	175·950544	230·632239	304·243523
42½	83·740757	107·390532	139·065211	181·644890	239·059387	316·669525
43	85·483892	110·012381	142·993338	187·507577	247·776496	329·583005
43½	87·252980	112·686153	147·018471	193·543583	256·793544	343·003087
44	89·048409	115·412876	151·143005	199·758031	266·120851	356·949645
44½	90·870570	118·193599	155·369395	206·156198	275·769092	371·443334
45	92·719861	121·029392	159·700155	212·743513	285·749310	386·505617
45½	94·596687	123·921343	164·137865	219·525570	296·072928	402·158801
46	96·501457	126·870567	168·685163	226·508124	306·751762	418·426066
46½	98·434587	129·878197	173·344758	233·697104	317·798033	435·331505
47	100·396500	132·945390	178·119421	241·098612	329·224385	452·900152
47½	102·387625	136·073325	183·011996	248·718930	341·043896	471·158026
48	104·408395	139·263206	188·025392	256·564528	353·270093	490·132164
48½	106·459254	142·516258	193·162596	264·642066	365·916969	509·850668
49	108·540647	145·833734	198·426662	272·958400	378·998999	530·342737
49½	110·653031	149·216908	203·820725	281·520590	392·531156	551·638721
50	112·796867	152·667083	209·347995	290·335904	406·528929	573·770156

The Third Table of Compound Interest—*continued.*

The Amount of One Pound per Annum in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
50½	114·972622	156·185585	215·011762	299·411826	421·008337	596·769819
51	117·180773	159·773767	220·815395	308·756058	435·985954	620·671768
51½	119·421801	163·433008	226·762350	318·376535	451·478921	645·511405
52	121·696196	167·164717	232·856165	328·281422	467·504971	671·325510
52½	124·004455	170·970329	239·100467	338·479127	484·082445	698·152317
53	126·347082	174·851306	245·498973	348·978307	501·230319	726·031551
53½	128·724589	178·809142	252·055491	359·787875	518·968217	755·004502
54	131·137494	182·845358	258·773922	370·917006	537·316441	785·114075
54½	133·586326	186·961507	265·658265	382·375148	556·295992	816·404863
55	136·071619	191·159173	272·712618	394·172026	575·928592	848·923201
55½	138·593916	195·439968	279·941178	406·317657	596·236711	882·717252
56	141·153768	199·805539	287·348249	418·822348	617·243594	917·837057
56½	143·751734	204·257567	294·938237	431·696716	638·973281	954·334632
57	146·388381	208·797761	302·715661	444·951689	661·450645	992·264022
57½	149·064286	213·427869	310·685149	458·598519	684·701411	1031·681403
58	151·780032	218·149672	318·851444	472·648790	708·752190	1072·645143
58½	154·536214	222·964984	327·219407	487·114430	733·630510	1115·215915
59	157·333433	227·875658	335·794017	502·007717	759·364844	1159·456755
59½	160·172301	232·883583	344·580377	517·341296	785·984645	1205·433188
60	163·053436	237·990685	353·583717	533·128180	813·520383	1253·213295
60½	165·977470	243·198927	362·809396	549·381774	842·003571	1302·867843
61	168·945039	248·510312	372·262903	566·115871	871·466810	1354·470359
61½	171·956794	253·926884	381·949866	583·344680	901·943821	1408·097271
62	175·013391	259·450725	391·876048	601·082824	933·469486	1463·827988
62½	178·115498	265·083959	402·047359	619·345361	966·079888	1521·745052
63	181·263792	270·828754	412·469851	638·147793	999·812350	1581·934227
63½	184·458963	276·687318	423·149727	657·506083	1034·705480	1644·484656
64	187·701706	282·661904	434·093343	677·436661	1070·799215	1709·488965
64½	190·992732	288·754810	445·307214	697·956448	1108·134864	1777·043429
65	194·332757	294·968380	456·798011	719·082860	1146·755160	1847·248082
65½	197·722513	301·305003	468·572574	740·833835	1186·704304	1920·206903
66	201·162740	307·767115	480·637911	763·227832	1228·028021	1996·027929
66½	204·654189	314·357203	493·001203	786·283865	1270·773606	2074·823456
67	208·197622	321·077800	505·669807	810·021502	1314·989983	2156·710163
67½	211·793815	327·931491	518·651263	834·460897	1360·727758	2241·809332
68	215·443551	334·920912	531·953297	859·622792	1408·039282	2330·246976
68½	219·147629	342·048751	545·583826	885·528550	1456·978701	2422·154079
69	222·906858	349·317748	559·550962	912·200160	1507·602032	2517·666734
69½	226·722058	356·730701	573·863018	939·660263	1559·967211	2616·926405
70	230·594063	364·290458	588·528510	967·932169	1614·134174	2720·080073
70½	234·523720	371·999929	603·556169	997·039879	1670·164915	2827·280518
71	238·511885	379·862077	618·954936	1027·008099	1728·123566	2938·686479
71½	242·559431	387·879926	634·733977	1057·862272	1788·076459	3054·462959
72	246·667242	396·056560	650·902683	1089·628585	1850·092216	3174·781398
72½	250·836214	404·395123	667·470676	1122·334008	1914·241812	3299·819996
73	255·067259	412·898822	684·447817	1156·006300	1980·598671	3429·763909
73½	259·361301	421·570928	701·844210	1190·674049	2049·238738	3564·805596
74	263·719277	430·414775	719·670208	1226·366679	2120·240578	3705·145022
74½	268·142140	439·433765	737·936420	1263·114492	2193·685450	3850·990043
75	272·630855	448·631366	756·653718	1300·948679	2269·657418	4002·556624

THE THIRD TABLE OF COMPOUND INTEREST — *continued.*

The Amount of One Pound per Annum in any Number of Years, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
75½	277·186404	458·011116	775·833241	1339·901361	2348·243432	4160·069247
76	281·809781	467·576621	795·486404	1380·005600	2429·533437	4323·761154
76½	286·501996	477·331560	815·624903	1421·295443	2513·620472	4493·874786
77	291·264074	487·279686	836·260724	1463·805936	2600·600778	4670·662046
77½	296·097056	497·424823	857·406149	1507·573170	2690·573905	4854·384769
78	301·001996	507·770873	879·073760	1552·634292	2783·642833	5045·315010
78½	305·979968	518·321816	901·276456	1599·027560	2879·914078	5243·735551
79	311·052056	529·081708	924·027448	1646·792350	2979·497831	5449·940211
79½	316·159367	540·054688	947·340279	1695·969214	3082·508064	5664·234395
80	321·363018	551·244976	971·228821	1746·599891	3189·062679	5886·935428
80½	326·644148	562·656876	995·707293	1798·727367	3299·283628	6118·373147
81	332·003909	574·294775	1020·790262	1852·395884	3413·297067	6358·890262
81½	337·443472	586·163151	1046·492658	1907·651009	3531·233482	6608·842999
82	342·964026	598·266566	1072·829775	1964·539637	3653·227861	6868·601483
82½	348·566776	610·609677	1099·817290	2023·110069	3779·419826	7138·550438
83	354·252947	623·197229	1127·471264	2083·412016	3909·953812	7419·089602
83½	360·023780	636·034064	1155·808155	2145·496673	4044·979214	7710·634474
84	365·880535	649·125118	1184·844827	2209·416737	4184·650579	8013·616770
84½	371·824493	662·475427	1214·598563	2275·226474	4329·127759	8328·485232
85	377·856951	676·090123	1245·087068	2342·981741	4478·576119	8655·706112
85½	383·979228	689·974444	1276·328491	2412·740062	4633·166702	8995·764050
86	390·192660	704·133728	1308·341422	2484·560645	4793·076448	9349·162600
86½	396·498605	718·573422	1341·144916	2558·504466	4958·488372	9716·425174
87	402·898440	733·299077	1374·758493	2634·634284	5129·591799	10098·095609
87½	409·393563	748·316358	1409·202161	2713·014734	5306·582558	10494·739188
88	415·985393	763·631040	1444·496418	2793·712341	5489·663225	10906·943257
88½	422·675370	779·249013	1480·662269	2876·795618	5679·043337	11335·318323
89	429·464955	795·176282	1517·721238	2962·335082	5874·939651	11780·498718
89½	436·355631	811·418973	1555·695383	3050·403355	6077·576370	12243·143789
90	443·348903	827·983333	1594·607300	3141·075187	6287·185426	12723·938615
90½	450·446300	844·875732	1634·480152	3234·427556	6504·006716	13223·595292
91	457·649370	862·102667	1675·337665	3330·539698	6728·288406	13742·853705
91½	464·959689	879·670762	1717·204160	3429·493210	6960·287186	14282·482916
92	472·378851	897·586773	1760·104549	3531·372080	7200·268595	14843·282001
92½	479·908480	915·857592	1804·064368	3636·262802	7448·507289	15426·081549
93	487·550217	934·490244	1849·109776	3744·254405	7705·287396	16031·744561
93½	495·305734	953·491896	1895·267586	3855·438571	7970·902800	16661·168073
94	503·176723	972·869854	1942·565265	3969·909669	8245·657514	17315·284126
94½	511·164906	992·631572	1991·030965	4087·764885	8529·865996	17995·061519
95	519·272025	1012·784648	2040·693528	4209·104249	8823·853540	18701·506856
95½	527·499853	1033·336834	2091·582514	4334·030778	9127·956615	19435·666440
96	535·850186	1054·296034	2143·728205	4462·650504	9442·523288	20198·627405
96½	544·324849	1075·670308	2197·161639	4595·072625	9767·913579	20991·519756
97	552·925692	1097·467875	2251·914615	4731·409534	10104·499918	21815·517597
97½	561·654594	1119·697120	2308·019721	4871·776982	10452·667529	22671·841336
98	570·513462	1142·366590	2365·510346	5016·294106	10812·814912	23561·759005
98½	579·504232	1165·485005	2424·420708	5165·083601	11185·354256	24486·588643
99	588·628866	1189·061254	2484·785863	5318·271753	11570·711956	25447·699726
99½	597·889359	1213·104405	2546·641743	5475·988617	11969·329054	26446·515734
100	607·287732	1237·623704	2610·025156	5638·368058	12381·661793	27484·515704

The Fourth Table of Compound Interest.

The present Value of One Pound per Annum for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
½	·489024	·485483	·481998	·478568	·475193	·471869
1	·970873	·961538	·952380	·943396	·934579	·925925
1½	1·445654	1·428349	1·411427	1·394876	1·378685	1·362842
2	1·913469	1·886094	1·859410	1·833392	1·808018	1·783264
2½	2·374421	2·334951	2·296597	2·259317	2·223070	2·187816
3	2·828611	2·775091	2·723248	2·673011	2·624316	2·577096
3½	3·276137	3·206683	3·139616	3·074827	3·012215	2·951682
4	3·717098	3·629895	3·545950	3·465105	3·387211	3·312126
4½	4·151589	4·044888	3·942491	3·844177	3·749733	3·658964
5	4·579707	4·451822	4·329476	4·212363	4·100197	3·992710
5½	5·001543	4·850854	4·707135	4·569978	4·439003	4·313856
6	5·417191	5·242136	5·075692	4·917324	4·766539	4·622879
6½	5·826741	5·625821	5·435366	5·254696	5·083180	4·920237
7	6·230282	6·002054	5·786373	5·582381	5·389289	5·206370
7½	6·627904	6·370981	6·128920	5·900657	5·685215	5·481701
8	7·019692	6·732744	6·463212	6·209793	5·971298	5·746638
8½	7·405732	7·087482	6·789448	6·510053	6·247865	6·001575
9	7·786108	7·435331	7·107821	6·801692	6·515232	6·246887
9½	8·160905	7·776425	7·418522	7·084956	6·773705	6·482940
10	8·530202	8·110895	7·721734	7·360087	7·023581	6·710081
10½	8·894082	8·438870	8·017640	7·627317	7·265145	6·928648
11	9·252624	8·760476	8·306414	7·886874	7·498674	7·138964
11½	9·605905	9·075837	8·588228	8·138978	7·724435	7·341340
12	9·954003	9·385073	8·863251	8·383843	7·942686	7·536078
12½	10·296995	9·688305	9·131646	8·621678	8·153677	7·723463
13	10·634955	9·985647	9·393572	8·852682	8·357650	7·903775
13½	10·967956	10·277216	9·649187	9·077054	8·554838	8·077281
14	11·296073	10·563122	9·898640	9·294983	8·745467	8·244236
14½	11·619375	10·843477	10·142082	9·506655	8·929756	8·404890
15	11·937935	11·118387	10·379658	9·712248	9·107914	8·559478
15½	12·251821	11·387958	10·611507	9·911939	9·280145	8·708231
16	12·561102	11·652295	10·837769	10·105895	9·446648	8·851369
16½	12·865845	11·911499	11·058578	10·294282	9·607612	8·989103
17	13·166118	12·165668	11·274066	10·477259	9·763222	9·121638
17½	13·461986	12·414902	11·484360	10·654983	9·913656	9·249169
18	13·753513	12·659296	11·689586	10·827603	10.059086	9·371887
18½	14·040763	12·898945	11·889867	10·995267	10·199679	9·489971
19	14·323799	13·133939	12·085320	11·158116	10·335595	9·603599
19½	14·602682	13·364370	12·276064	11·316289	10·466990	9·712937
20	14·877474	13·590326	12·462210	11·469921	10·594014	9·818147
20½	15·148235	13·811894	12·643870	11·619141	10·716813	9·919386
21	15·415024	14·029159	12·821152	11·764076	10·835527	10·016803
21½	15·677898	14·242206	12·994162	11·904850	10·950292	10·110542
22	15·936916	14·451115	13·163002	12·041581	11·061240	10·200743
22½	16·192134	14·655967	13·327773	12·174387	11·168497	10·287539
23	16·443608	14·856841	13·488573	12·303378	11·272187	10·371058
23½	16·691392	15·053814	13·645498	12·428667	11·372427	10·451425
24	16·935542	15·246963	13·798641	12·550357	11·469334	10·528758
24½	17·176109	15·436360	13·948094	12·668553	11·563016	10·603171
25	17·413147	15·622079	14·093944	12·783356	11·653583	10·674776

THE FOURTH TABLE OF COMPOUND INTEREST—*continued.*

The present Value of One Pound per Annum for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
25½	17·646708	15·804192	14·236280	12·894862	11·741137	10·743677
26	17·876842	15·982769	14·375185	13·003166	11·825778	10·809977
26½	18·103600	16·157877	14·510742	13·108360	11·907604	10·873775
27	18·327031	16·329585	14·643033	13·210534	11·986709	10·935164
27½	18·547184	16·497959	14·772136	13·309774	12·063182	10·994236
28	18·764108	16·663063	14·898127	13·406164	12·137111	11·051078
28½	18·977849	16·824960	15·021082	13·499786	12·208581	11·105774
29	19·188454	16·983714	15·141073	13·590721	12·277674	11·158406
29½	19·395970	17·139385	15·258173	13·679044	12·344468	11·209050
30	19·600441	17·292033	15·372451	13·764831	12·409041	11·257783
30½	19·801912	17·441716	15·483974	13·848154	12·471465	11·304676
31	20·000428	17·588493	15·592810	13·929085	12·531814	11·349799
31½	20·196031	17·732419	15·699023	14·007693	12·590155	11·393218
32	20·388765	17·873551	15·802676	14·084043	12·646555	11·434999
32½	20·578671	18·011942	15·903831	14·158201	12·701079	11·475202
33	20·765791	18·147645	16·002549	14·230229	12·753790	11·513888
33½	20·950166	18·280713	16·098887	14·300189	12·804747	11·551113
34	21·131836	18·411197	16·192904	14·368141	12·854009	11·586933
34½	21·310841	18·539147	16·284654	14·434141	12·901632	11·621401
35	21·487220	18·664613	16·374194	14·498246	12·947672	11·654568
35½	21·661011	18·787642	16·461575	14·560510	12·992180	11·686482
36	21·832252	18·908281	16·546851	14·620987	13·035207	11·717192
36½	22·000981	19·026578	16·630072	14·679727	13·076804	11·746743
37	22·167235	19·142578	16·711287	14·736780	13·117016	11·775178
37½	22·331050	19·256325	16·790545	14·792195	13·155891	11·802540
38	22·492461	19·367864	16·867892	14·846019	13·193473	11·828868
38½	22·651505	19·477236	16·943376	14·898297	13·229805	11·854203
39	22·808215	19·584484	17·017040	14·949074	13·264928	11·878582
39½	22·962626	19·689650	17·088929	14·998393	13·298883	11·902040
40	23·114771	19·792773	17·159086	15·046296	13·331708	11·924613
40½	23·264685	19·893894	17·227552	15·092824	13·363442	11·946333
41	23·412399	19·993051	17·294367	15·138015	13·394120	11·967234
41½	23·557947	20·090283	17·359573	15·181909	13·423777	11·987346
42	23·701359	20·185626	17·423207	15·224543	13·452448	12·006698
42½	23·842667	20·279118	17·485308	15·265952	13·480166	12·025320
43	23·981902	20·370794	17·545911	15·306172	13·506961	12·043239
43½	24·119094	20·460690	17·605055	15·345238	13·532865	12·060482
44	24·254273	20·548841	17·662773	15·383182	13·557908	12·077073
44½	24·387470	20·635279	17·719100	15·420036	13·582117	12·093038
45	24·518712	20·720039	17·774069	15·455832	13·605521	12·108401
45½	24·648029	20·803153	17·827714	15·490600	13·628147	12·123184
46	24·775449	20·884653	17·880066	15·524369	13·650020	12·137408
46½	24·900999	20·964570	17·931156	15·557169	13·671165	12·151096
47	25·024707	21·042936	17·981015	15·589028	13·691607	12·164267
47½	25·146601	21·119779	18·029673	15·619971	13·711369	12·176941
48	25·266706	21·195130	18·077157	15·650026	13·730474	12·189136
48½	25·385049	21·269018	18·123498	15·679218	13·748943	12·200871
49	25·501656	21·341472	18·168721	15·707572	13·766798	12·212163
49½	25·616553	21·412518	18·212855	15·735111	13·784059	12·223029
50	25·729763	21·482184	18·255925	15·761860	13·800746	12·233484

THE FOURTH TABLE OF COMPOUND INTEREST — *continued.*

The present Value of One Pound per Annum for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
50½	25·841313	21·550498	18·297957	15·787841	13·816878	12·243545
51	25·951227	21·617485	18·338976	15·813076	13·832473	12·253226
51½	26·059528	21·683171	18·379007	15·837586	13·847549	12·262542
52	26·166239	21·747581	18·418072	15·861392	13·862124	12·271506
52½	26·271386	21·810741	18·456197	15·884515	13·876214	12·280131
53	26·374990	21·872674	18·493402	15·906974	13·889835	12·288431
53½	26·477074	21·933405	18·529711	15·928788	13·903004	12·296418
54	26·577660	21·992956	18·565145	15·949975	13·915734	12·304103
54½	26·676771	22·051351	18·599725	15·970554	13·928041	12·311498
55	26·774427	22·108612	18·633471	15·990542	13·939938	12·318614
55½	26·870651	22·164760	18·666405	16·009957	13·951440	12·325461
56	26·965463	22·219819	18·698544	16·028814	13·962559	12·332050
56½	27·058884	22·273808	18·729909	16·047129	13·973308	12·338390
57	27·150935	22·326749	18·760518	16·064918	13·983700	12·344490
57½	27·241635	22·378662	18·790390	16·082197	13·993746	12·350361
58	27·331005	22·429566	18·819541	16·098980	14·003458	12·356010
58½	27·419063	22·479482	18·847990	16·115280	14·012847	12·361445
59	27·505830	22·528429	18·875754	16·131113	14·021923	12·366675
59½	27·591324	22·576425	18·902848	16·146491	14·030698	12·371708
60	27·675563	22·623489	18·929289	16·161427	14·039181	12·376551
60½	27·758567	22·669640	18·955093	16·175935	14·047381	12·381211
61	27·840353	22·714894	18·980275	16·190026	14·055309	12·385696
61½	27·920939	22·759269	19·004851	16·203712	14·062973	12·390011
62	28·000342	22·802782	19·028834	16·217005	14·070382	12·394163
62½	28·078581	22·845451	19·052239	16·229917	14·077545	12·398158
63	28·155672	22·887291	19·075080	16·242458	14·084469	12·402002
63½	28·231632	22·928318	19·097370	16·254639	14·091163	12·405702
64	28·306478	22·968549	19·119123	16·266470	14·097635	12·409261
64½	28·380225	23·007998	19·140352	16·277961	14·103891	12·412687
65	28·452891	23·046681	19·161070	16·289122	14·109939	12·415983
65½	28·524491	23·084614	19·181288	16·299963	14·115786	12·419154
66	28·595040	23·121809	19·201019	16·310493	14·121438	12.422206
66½	28·664554	23·158282	19·220274	16·320720	14·126903	12·425143
67	28·733048	23·194047	19·239066	16·330653	14·132185	12·427969
67½	28·800538	23·229118	19·257404	16·340302	14·137292	12·430688
68	28·867037	23·263507	19·275301	16·349673	14·142229	12·433304
68½	28·932561	23·297228	19·292766	16·358775	14·147002	12·435822
69	28·997123	23·330295	19·309810	16·367616	14·151616	12·438245
69½	29·060739	23·362720	19·326444	16·376203	14·156077	12·440576
70	29·123421	23·394514	19·342676	16·384543	14·160389	12·442819
70½	29·185183	23·425692	19·358518	16·392644	14·164558	12·444978
71	29·246040	23·456264	19·373977	16·400513	14·168588	12·447055
71½	29·306003	23·486242	19·389064	16·408155	14·172484	12·449053
72	29·365087	23·515638	19·403788	16·415578	14·176250	12·450977
72½	29·423304	23·544464	19·418157	16·422788	14·179891	12·452827
73	29·480667	23·572729	19·432179	16·429790	14·183411	12·454608
73½	29·537188	23·600446	19·445863	16·436592	14·186814	12·456321
74	29·592881	23·627624	19·459218	16·443198	14·190104	12 457970
74½	29·647756	23·654275	19·472251	16·449615	14·193284	12·459557
75	29·701826	23·680408	19·484969	16·455848	14·196359	12·461083

THE FOURTH TABLE OF COMPOUND INTEREST — *continued.*

The present Value of One Pound per Annum for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
75½	29·755103	23·706033	19·497382	16·461901	14·199331	12·462553
76	29·807598	23·731161	19·509495	16·467781	14·202204	12·463966
76½	29·859323	23·755801	19·521316	16·473492	14·204982	12·465326
77	29·910289	23·779963	19·532852	16·479038	14·207668	12·466635
77½	29·960508	23·803655	19·544110	16·484426	14·210264	12·467895
78	30·009989	23·826887	19·555097	16·489659	14·212774	12·469107
78½	30·058745	23·849668	19·565819	16·494741	14·215200	12·470273
79	30·106786	23·872007	19·576283	16·499678	14·217545	12·471395
79½	30·154122	23·893912	19·586495	16·504473	14·219813	12·472475
80	30·200763	23·915391	19·596460	16·509130	14·222005	12·473514
80½	30·246720	23·936454	19·606185	16·513654	14·224124	12·474514
81	30·292003	23·957107	19·615676	16·518047	14·226173	12·475476
81½	30·336621	23·977359	19·624938	16·522315	14·228153	12·476402
82	30·380585	23·997218	19·633977	16·526460	14·230068	12·477292
82½	30·423904	24·016692	19·642798	16·530486	14·231919	12·478150
83	30·466588	24·035787	19·651407	16·534396	14·233708	12·478974
83½	30·508645	24·054511	19·659808	16·538194	14·235438	12·479768
84	30·550085	24·072872	19·668007	16·541883	14·237111	12·480532
84½	30·590917	24·090876	19·676008	16·545466	14·238727	12·481267
85	30·631151	24·108531	19·683816	16·548946	14·240290	12·481974
85½	30·670794	24·125842	19·691436	16·552326	14·241801	12·482654
86	30·709855	24·142818	19·698872	16·555610	14·243262	12·483309
86½	30·748343	24·159464	19·706129	16·558798	14·244674	12·483939
87	30·786267	24·175786	19·713212	16·561896	14·246039	12·484545
87½	30·823634	24·191792	19·720123	16·564904	14·247359	12·485129
88	30·860453	24·207487	19·726868	16·567826	14·248635	12·485690
88½	30·896732	24·222877	19·733451	16·570664	14·249868	12·486230
89	30·932479	24·237968	19·739874	16·573421	14·251060	12·486750
89½	30·967701	24·252766	19·746143	16·576098	14·252213	12·487250
90	31·002407	24·267277	19·752261	16·578699	14·253327	12·487732
90½	31·036603	24·281506	19·758232	16·581225	14·254405	12·488195
91	31·070298	24·295459	19·764058	16·583678	14·255446	12·488640
91½	31·103498	24·309140	19·769744	16·586061	14·256453	12·489069
92	31·136211	24·322556	19·775294	16·588376	14·257426	12·489482
92½	31·168445	24·335712	19·780709	16·590624	14·258367	12·489879
93	31·200205	24·348612	19·785994	16·592807	14·259277	12·490261
93½	31·231500	24·361261	19·791151	16·594928	14·260156	12·490628
94	31·262335	24·373665	19·796185	16·596988	14·261006	12·490982
94½	31·292718	24·385828	19·801097	16·598989	14·261828	12·491323
95	31·322655	24·397755	19·805890	16·600932	14·262623	12·491650
95½	31·352154	24·409450	19·810568	16·602819	14·263391	12·491965
96	31·381219	24·420918	19·815133	16·604653	14·264133	12·492269
96½	31·409858	24·432164	19·819589	16·606433	14·264851	12·492560
97	31·438077	24·443191	19·823937	16·608163	14·265545	12·492841
97½	31·465881	24·454004	19·828180	16·609843	14·266216	12·493111
98	31·493278	24·464606	19·832321	16·611474	14·266865	12·493372
98½	31·520273	24·475003	19·836362	16·613059	14·267492	12·493622
99	31·546872	24·485198	19·840305	16·614599	14·268098	12·493862
99½	31·573081	24·495196	19·844154	16·616094	14·268684	12·494094
100	31·598905	24·504998	19·847910	16·617546	14·269250	12·494317
S. F.	33·333333	25·000000	20·000000	16·666666	14·285714	12·500000

THE FIFTH TABLE OF COMPOUND INTEREST.

The Annuity which One Pound will purchase for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
1	1·030000	1·040000	1·050000	1·060000	1·070000	1·080000
1½	·691728	·700108	·708502	·716909	·725328	·733760
2	·522610	·530196	·537804	·545436	·553091	·560769
2½	·421155	·428274	·435426	·442611	·449828	·457076
3	·353530	·360348	·367208	·374109	·381051	·388033
3½	·305237	·311848	·318510	·325221	·331981	·338789
4	·269027	·275490	·282011	·288591	·295228	·301920
4½	·240871	·247225	·253646	·260133	·266685	·273301
5	·218354	·224627	·230974	·237396	·243890	·250456
5½	·199938	·206149	·212443	·218819	·225275	·231811
6	·184597	·190761	·197017	·203362	·209795	·216315
6½	·171622	·177751	·183980	·190805	·196727	·203242
7	·160506	·166609	·172819	·179135	·185553	·192072
7½	·150877	·156961	·163160	·169472	175894	·182425
8	·142456	·148527	·154721	·161035	·167467	·174014
8½	·135030	·141093	·147287	·153608	·160054	·166622
9	·128433	·134492	·140690	·147022	·153486	·160079
9½	·122535	·128593	·134797	·141144	·147629	·154251
10	·117230	·123290	·129504	·135867	·142377	·149029
10½	·112434	·118499	·124724	·131107	·137643	·144328
11	·108077	·114149	·120388	·126792	·133356	·140076
11½	·104102	·110182	·116438	·122865	·129459	·136214
12	·100462	·106552	·112825	·119277	·125901	·132695
12½	·097115	·103217	·109509	·115986	·122644	·129475
13	·094029	·100143	·106455	·112960	·119650	·126521
13½	·091174	·097302	·103635	·110167	·116892	·123804
14	·088526	·094668	·101023	·107584	·114344	·121296
14½	·086063	·092221	·098599	·105189	·111985	·118978
15	·083766	·089941	·096342	·102962	·109794	·116829
15½	·081620	·087812	·094237	·100888	·107756	·114833
16	·079610	·085820	·092269	·098952	·105857	·112976
16½	·077725	·083952	·090427	·097141	·104084	·111245
17	·075952	·082198	·088699	·095444	·102425	·109629
17½	·074283	·080548	·087074	·093852	·100870	·108117
18	·072708	·078993	·085546	·092356	·099412	·106702
18½	·071221	·077525	·084105	·090948	·098042	·105374
19	·069813	·076138	·082745	·089620	·096753	·104127
19½	·068480	·074825	·081459	·088368	·095538	·102955
20	·067215	·073581	·080242	·087184	·094392	·101852
20½	·066014	·072401	·079089	·086064	·093311	·100812
21	·064871	·071280	·077996	·085004	·092289	·099832
21½	·063784	·070213	·076957	·083999	·091321	·098906
22	·062747	·069198	·075970	·083045	·090405	·098032
22½	·061758	·068231	·075031	·082139	·089537	·097204
23	·060813	·067309	·074136	·081278	·088713	·096422
23½	·059911	·066428	·073284	·080459	·087931	·095680
24	·059047	·065586	·072470	·079679	·087189	·094977
24½	·058220	·064782	·071694	·078935	·086482	·094311
25	·057427	·064011	·070952	·078226	·085810	·093678

THE FIFTH TABLE OF COMPOUND INTEREST—*continued.*

The Annuity which One Pound will purchase for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
25½	·056667	·063274	·070243	·077550	·085170	·093078
26	·055938	·062567	·069564	·076904	·084561	·092507
26½	·055237	·061889	·068914	·076287	·083979	·091964
27	·054564	·061238	·068291	·075697	·083425	·091448
27½	·053916	·060613	·067695	·075132	·082896	·090956
28	·053293	·060012	·067122	·074592	·082391	·090488
28½	·052693	·059435	·066573	·074075	·081909	·090043
29	·052114	·058879	·066045	·073579	·081448	·089618
29½	·051557	·058345	·065538	·073104	·081007	·089213
30	·051019	·057830	·065051	·072648	·080586	·088827
30½	·050500	·057333	·064582	·072211	·080183	·088458
31	·049998	·056855	·064132	·071792	·079796	·088107
31½	·049514	·056393	·063698	·071389	·079427	·087771
32	·049046	·055948	·063280	·071002	·079072	·087450
32½	·048594	·055518	·062877	·070630	·078733	·087144
33	·048156	·055103	·062490	·070272	·078408	·086851
33½	·047732	·054702	·062116	·069929	·078096	·086571
34	·047321	·054314	·061755	·069598	·077796	·086304
34½	·046924	·053939	·061407	·069280	·077509	·086048
35	·046539	·053577	·061071	·068973	·077233	·085803
35½	·046165	·053226	·060747	·068678	·076969	·085568
36	·045803	·052886	·060434	·068394	·076715	·085344
36½	·045452	·052558	·060132	·068121	·076471	·085129
37	·045111	·052239	·059839	·067857	·076236	·084924
37½	·044780	·051930	·059557	·067603	·076011	·084727
38	·044459	·051631	·059284	·067358	·075795	·084538
38½	·044147	·051341	·059020	·067121	·075586	·084358
39	·043843	·051060	·058764	·066893	·075386	·084185
39½	·043549	·050788	·058517	·066673	·075194	·084019
40	·043262	·050523	·058278	·066461	·075009	·083860
40½	·042983	·050266	·058046	·066256	·074831	·083707
41	·042712	·050017	·057822	·066058	·074659	·083561
41½	·042448	·049775	·057605	·065867	·074494	·083421
42	·042191	·049540	·057394	·065683	·074335	·083286
42½	·041941	·049311	·057190	·065505	·074183	·083157
43	·041698	·049089	·056993	·065333	·074035	·083034
43½	·041460	·048874	·056801	·065166	·073894	·082915
44	·041229	·048664	·056616	·065006	·073757	·082801
44½	·041004	·048460	·056436	·064850	·073626	·082692
45	·040785	·048262	·056261	·064700	·073499	·082587
45½	·040571	·048069	·056092	·064555	·073377	·082486
46	·040362	·047882	·055928	·064414	·073259	·082389
46½	·040159	·047699	·055768	·064279	·073146	·082297
47	·039960	·047521	·055614	·064147	·073037	·082207
47½	·039766	·047348	·055464	·064020	·072932	·082122
48	·039577	·047180	·055318	·063897	·072830	·082040
48½	·039393	·047016	·055176	·063778	·072732	·081961
49	·039213	·046857	·055039	·063663	·072638	·081885
49½	·039037	·046701	·054906	·063552	·072547	·081812
50	·038865	·046550	·054776	·063444	·072459	·081742

THE FIFTH TABLE OF COMPOUND INTEREST — *continued.*

The Annuity which One Pound will purchase for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent.	8 per Cent.
50½	·038697	·046402	·054650	·063339	·072375	·081675
51	·038533	·046258	·054528	·063238	·072293	·081611
51½	·038373	·046118	·054409	·063140	·072214	·081549
52	·038217	·045982	·054294	·063046	·072139	·081489
52½	·038064	·045848	·054182	·062954	·072065	·081432
53	·037914	·045719	·054073	·062865	·071995	·081377
53½	·037768	·045592	·053967	·062779	·071926	·081324
54	·037625	·045469	·053864	·062696	·071861	·081273
54½	·037485	·045348	·053764	·062615	·071797	·081224
55	·037349	·045231	·053666	·062536	·071736	·081177
55½	·037215	·045116	·053572	·062461	·071677	·081132
56	·037084	·045004	·053480	·062387	·071620	·081089
56½	·036956	·044895	·053390	·062316	·071565	·081047
57	·036831	·044789	·053303	·062247	·071511	·081007
57½	·036708	·044685	·053218	·062180	·071460	·080969
58	·036588	·044584	·053136	·062115	·071410	·080932
58½	·036470	·044485	·053056	·062052	·071363	·080896
59	·036355	·044388	·052978	·061992	·071316	·080862
59½	·036243	·044293	·052902	·061932	·071272	·080829
60	·036132	·044201	·052828	·061875	·071229	·080797
60½	·036024	·044111	·052756	·061820	·071187	·080767
61	·035919	·044023	·052686	·061766	·071147	·080738
61½	·035815	·043938	·052618	·061714	·071108	·080710
62	·035713	·043854	·052551	·061663	·071071	·080683
62½	·035614	·043772	·052487	·061614	·071035	·080657
63	·035516	·043692	·052424	·061567	·071000	·080632
63½	·035421	·043614	·052363	·061520	·070966	·080608
64	·035327	·043537	·052303	·061476	·070933	·080584
64½	·035235	·043463	·052245	·061432	·070902	·080562
65	·035145	·043390	·052189	·061390	·070872	·080541
65½	·035057	·043318	·052134	·061349	·070842	·080520
66	·034971	·043249	·052080	·061310	·070814	·080501
66½	·034886	·043181	·052028	·061271	·070786	·080481
67	·034803	·043114	·051977	·061234	·070760	·080463
67½	·034721	·043049	·051928	·061198	·070734	·080446
68	·034641	·042985	·051879	·061163	·070710	·080429
68½	·034563	·042923	·051832	·061129	·070686	·080412
69	·034486	·042862	·051787	·061096	·070663	·080397
69½	·034410	·042803	·051742	·061064	·070641	·080382
70	·034336	·042745	·051699	·061033	·070619	·080367
70½	·034263	·042688	·051656	·061002	·070598	·080353
71	·034192	·042632	·051615	·060973	·070578	·080340
71½	·034122	·042578	·051575	·060945	·070559	·080327
72	·034054	·042524	·051536	·060917	·070540	·080314
72½	·033986	·042472	·051498	·060891	·070522	·080303
73	·033920	·042421	·051461	·060865	·070504	·080291
73½	·033855	·042372	·051424	·060839	·070487	·080280
74	·033791	·042323	·051389	·060815	·070471	·080269
74½	·033729	·042275	·051355	·060791	·070455	·080259
75	·033667	·042229	·051321	·060768	·070440	·080249

The Fifth Table of Compound Interest — *continued.*

The Annuity which One Pound will purchase for any Number of Years to come, &c.

Years.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	7 per Cent	8 per Cent.
75½	·033607	·042188	·051288	·060746	·070425	·080240
76	·033548	·042138	·051257	·060724	·070411	·080231
76½	·033490	·042094	·051226	·060703	·070397	·080222
77	·033433	·042052	·051195	·060683	·070384	·080214
77½	·033377	·042010	·051166	·060663	·070371	·080206
78	·033322	·041969	·051137	·060644	·070359	·080198
78½	·033268	·041929	·051109	·060625	·070347	·080190
79	·033215	·041890	·051082	·060607	·070335	·080183
79½	·033162	·041851	·051055	·060589	·070324	·080176
80	·033111	·041814	·051029	·060572	·070313	·080169
80½	·033061	·041777	·051004	·060555	·070303	·080163
81	·033012	·041741	·050979	·060539	·070292	·080157
81½	·032963	·041706	·050955	·060524	·070283	·080151
82	·032915	·041671	·050932	·060509	·070273	·080145
82½	·032868	·041637	·050909	·060494	·070264	·080140
83	·032822	·041604	·050886	·060479	·070255	·080134
83½	·032777	·041572	·050865	·060466	·070247	·080129
84	·032733	·041540	·050843	·060452	·070238	·080124
84½	·032689	·041509	·050823	·060439	·070230	·080120
85	·032646	·041479	·050803	·060426	·070223	·080115
85½	·032604	·041449	·050783	·060414	·070215	·080111
86	·032562	·041420	·050764	·060402	·070208	·080106
86½	·032522	·041391	·050745	·060390	·070201	·080102
87	·032482	·041363	·050727	·060379	·070194	·080099
87½	·032442	·041336	·050709	·060368	·070188	·080095
88	·032403	·041309	·050692	·060357	·070182	·080091
88½	·032365	·041283	·050675	·060347	·070176	·080088
89	.032328	·041257	·050658	·060337	·070170	·080084
89½	·032291	·041232	·050642	·060327	·070164	·080081
90	·032255	·041207	·050627	·060318	·070159	·080078
90½	·032220	·041183	·050611	·060309	·070153	·080075
91	·032185	·041159	·050596	·060300	·070148	·080072
91½	·032150	·041136	·050582	·060291	·070143	·080070
92	·032116	·041114	·050568	·060283	·070138	·080067
92½	·032083	·041091	·050554	·060275	·070134	·080064
93	·032051	·041070	·050540	·060267	·070129	·080062
93½	·032018	·041048	·050527	·060259	·070125	·080060
94	·031987	·041027	·050514	·060251	·070121	·080057
94½	·031956	·041007	·050502	·060244	·070117	·080055
95	·031925	·040987	·050490	·060237	·070118	·080053
95½	·031895	·040967	·050478	·060280	·070109	·080051
96	·031866	·040948	·050466	·060224	·070105	·080049
96½	·031837	·040929	·050455	·060217	·070102	·080047
97	·031808	·040911	·050444	·060211	·070098	·080045
97½	·031780	·040893	·050433	·060205	·070095	·080044
98	·031752	·040875	·050422	·060199	·070092	·080042
98½	·031725	·040858	·050412	·060193	·070089	·080040
99	·031698	·040841	·050402	·060188	·070086	·080039
99½	·031672	·040824	·050392	·060182	·070083	·080037
100	·031646	·040808	·050383	·060177	·070080	·080036
F.S.	·030000	·040000	·050000	·060000	·070000	·080000

Table VI. Showing the Value of an Annuity on one Life according to the Probabilities of Life in London.

Age.	Year's value at			Age.	Year's value at		
	3 per Cent.	4 per Cent.	5 per Cent.		3 per Cent.	4 per Cent.	5 per Cent.
6	18·8	16·2	14·1	41	13·0	11·4	10·2
7	18·9	16·3	14·2	42	12·8	11·2	10·1
8	19·0	16·4	14·3	43	12·6	11·1	10·0
9 and 10	19·0	16·4	14·3	44	12·5	11·0	9·9
				45	12·3	10·8	9·8
				46	12·1	10·7	9·7
11	19·0	16·4	14·3	47	11·9	10·5	9·5
12	18·9	16·3	14·2	48	11·8	10·4	9·4
13	18·7	16·2	14·1	49	11·6	10·2	9·3
14	18·5	16·0	14·0	50	11·4	10·1	9·2
15	18·3	15·8	13·9	51	11·2	9·9	9·0
16	18·1	15·6	13·7	52	11·0	9·8	8·9
17	17·9	15·4	13·5	53	10·7	9·6	8·8
18	17·6	15·2	13·4	54	10·5	9·4	8·6
19	17·4	15·0	13·2	55	10·3	9·3	8·5
20	17·2	14·8	13·0	56	10·1	9·1	8·4
21	17·0	14·7	12·9	57	9·9	8·9	8·2
22	16·8	14·5	12·7	58	9·6	8·7	8·1
23	16·5	14·8	12·6	59	9·4	8·6	8·0
24	16·3	14·1	12·4	60	9·2	8·4	7·9
25	16·1	14·0	12·3	61	8·9	8·2	7·7
26	15·9	13·8	12·1	62	8·7	8·1	7·6
27	15·6	13·6	12·0	63	8·5	7·9	7·4
28	15·4	13·4	11·8	64	8·3	7·7	7·3
29	15·2	13·2	11·7	65	8·0	7·5	7·1
30	15·0	13·1	11·6	66	7·8	7·3	6·9
31	14·8	12·9	11·4	67	7·6	7·1	6·7
32	14·6	12·7	11·3	68	7·4	6·9	6·6
33	14·4	12·6	11·2	69	7·1	6·7	6·4
34	14·2	12·4	11·0	70	6·9	6·5	6·2
35	14·1	12·3	10·9	71	6·7	6·3	6·0
36	13·9	12·1	10·8	72	6·5	6·1	5·8
37	13·7	11·9	10·6	73	6·2	5·9	5·6
38	13·5	11·8	10·5	74	5·9	5·6	5·4
39	13·3	11·6	10·4	75	5·6	5·4	5·2
40	13·2	11·5	10·3				

TABLE VII., showing the Value of an Annuity on the joint Continuance of two Lives, according to the Probabilities of Life in London.

Age of the		Value at		
Younger.	Elder.	3 per Cent.	4 per Cent.	5 per Cent.
10	10	14·7	13·0	11·6
	15	14·3	12·7	11·3
	20	13·8	12·2	10·8
	25	13·1	11·6	10·2
	30	12·3	10·9	9·7
	35	11·5	10·2	9·1
	40	10·7	9·6	8·6
	45	10·0	9·0	8·1
	50	9·3	8·4	7·6
	55	8·6	7·8	7·1
	60	7·8	7·2	6·6
	65	6·9	6·5	6·1
	70	6·1	5·8	5·5
	75	5·3	5·1	4·9
15	15	13·9	12·3	11·0
	20	13·3	11·8	10·5
	25	12·6	11·2	10·1
	30	11·9	10·6	9·5
	35	11·2	10·0	9·0
	40	10·4	9·4	8·5
	45	9·6	8·8	8·0
	50	8·9	8·2	7·5
	55	8·2	7·6	7·0
	60	7·5	7·0	6·5
	65	6·8	6·4	6·0
	70	6·0	5·7	5·4
	75	5·2	5·0	4·8
20	20	12·8	11·3	10·1
	25	12·2	10·8	9·7
	30	11·6	10·3	9·2
	35	10·9	9·8	8·8
	40	10·2	9·2	8·4
	45	9·5	8·6	7·9
	50	8·8	8·0	7·4
	55	8·1	7·5	6·9
	60	7·4	6·9	6·4
	65	6·7	6·3	5·9
	70	6·0	5·7	5·4
	75	5·2	5·0	4·8
25	25	11·8	10·5	9·4
	30	11·3	10·1	9·0
	35	10·7	9·6	8·6
	40	10·0	9·1	8·2
	45	9·4	8·5	7·8
	50	8·7	7·9	7·3
	55	8·0	7·4	6·8
	60	7·3	6·8	6·3
	65	6·6	6·2	5·8
	70	5·9	5·6	5·3
	75	5·1	4·9	4·7
30	30	10·8	9·6	8·6
	35	10·3	9·2	8·3
	40	9·7	8·8	8·0
	45	9·1	8·3	7·6
	50	8·5	7·8	7·2
30	55	7·9	7·3	6·7
	60	7·2	6·7	6·2
	65	6·5	6·1	5·7
	70	5·8	5·5	5·2
	75	5·1	4·9	4·7
35	35	9·9	8·8	8·0
	40	9·4	8·5	7·7
	45	8·9	8·1	7·4
	50	8·3	7·6	7·0
	55	7·7	7·1	6·6
	60	7·1	6·5	6·1
	65	6·4	6·0	5·6
	70	5·7	5·4	5·1
	75	5·0	4·8	4·6
40	40	9·1	8·1	7·3
	45	8·7	7·8	7·1
	50	8·2	7·4	6·8
	55	7·6	6·9	6·4
	60	7·0	6·4	6·0
	65	6·4	5·9	5·5
	70	5·7	5·4	5·1
	75	5·0	4·8	4·6
45	45	8·3	7·4	6·7
	50	7·9	7·1	6·5
	55	7·4	6·7	6·2
	60	6·8	6·3	5·8
	65	6·3	5·8	5·4
	70	5·6	5·3	5·0
	75	4·9	4·7	4·5
50	50	7·6	6·8	6·2
	55	7·2	6·5	6·0
	60	6·7	6·1	5·7
	65	6·2	5·7	5·3
	70	5·5	5·2	4·9
	75	4·8	4·6	4·4
55	55	6·9	6·2	5·7
	60	6·5	5·9	5·5
	65	6·0	5·6	5·2
	70	5·4	5·1	4·8
	75	4·7	4·5	4·3
60	60	6·1	5·6	5·2
	65	5·7	5·3	4·9
	70	5·2	4·9	4·6
	75	4·6	4·4	4·2
65	65	5·4	5·0	4·7
	70	4·9	4·6	4·4
	75	4·4	4·2	4·0
70	70	4·6	4·4	4·2
	75	4·2	4·0	3·9
75	75	3·8	3·7	3·6

TABLE VIII., showing the Value of an Annuity on the longest of two Lives.

Age of the		Value at		
Younger.	Elder.	3 per Cent.	4 per Cent.	5 per Cent.
10	10	23·4	19·9	17·1
	15	22·9	19·5	16·8
	20	22·5	19·1	16·6
	25	22·2	18·8	16·4
	30	21·9	18·6	16·2
	35	21·6	18·4	16·1
	40	21·4	18·3	16·0
	45	21·2	18·2	15·9
	50	20·9	18·0	15·8
	55	20·7	17·8	15·7
	60	20·4	17·6	15·5
	65	20·1	17·4	15·3
	70	19·8	17·2	15·1
	75	19·5	16·9	14·8
15	15	22·8	19·3	16·7
	20	22·3	18·9	16·4
	25	21·9	18·6	16·2
	30	21·6	18·3	16·0
	35	21·3	18·1	15·9
	40	21·1	17·9	15·7
	45	20·9	17·8	15·6
	50	20·7	17·6	15·4
	55	20·4	17·4	15·3
	60	20·1	17·2	15·2
	65	19·8	16·9	15·0
	70	19·4	16·6	14·7
	75	18·9	16·3	14·4
20	20	21·6	18·3	15·8
	25	21·1	17·9	15·5
	30	20·7	17·6	15·3
	35	20·4	17·4	15·1
	40	20·1	17·2	15·0
	45	19·9	17·0	14·9
	50	19·6	16·8	14·7
	55	19·4	16·6	14·5
	60	19·1	16·3	14·3
	65	18·7	16·0	14·1
	70	18·2	15·7	13·8
	75	17·7	15·3	13·5
25	25	20·3	17·4	15·1
	30	19·8	17·0	14·9
	35	19·4	16·7	14·7
	40	19·2	16·5	14·5
	45	18·9	16·3	14·3
	50	18·7	16·1	14·2
	55	18·4	15·9	14·0
	60	18·0	15·6	13·8
	65	17·6	15·3	13·6
	70	17·2	15·0	13·3
	75	16·7	14·6	12·9
30	30	19·3	16·6	14·5
	35	18·8	16·2	14·2
	40	18·4	15·9	14·0
	45	18·1	15·6	13·8
	50	17·8	15·4	13·6
	55	17·4	15·1	13·4
	60	17·0	14·8	13·2
	65	16·6	14·5	12·9
	70	16·1	14·1	12·6
	75	15·6	13·7	12·2
35	35	18·3	15·8	13·8
	40	17·8	15·4	13·5
	45	17·4	15·1	13·3
	50	17·1	14·8	13·1
	55	16·7	14·5	12·9
	60	16·3	14·2	12·7
	65	15·8	13·8	12·4
	70	15·3	13·4	12·0
	75	14·8	13·0	11·6
40	40	17·3	15·0	13·3
	45	16·8	14·6	13·0
	50	16·3	14·0	12·7
	55	15·9	13·9	12·4
	60	15·4	13·5	12·1
	65	14·9	13·1	11·8
	70	14·5	12·7	11·4
	75	14·0	12·3	11·0
45	45	16·2	14·2	12·8
	50	15·7	13·8	12·5
	55	15·2	13·4	12·1
	60	14·7	12·9	11·7
	65	14·1	12·5	11·4
	70	13·6	12·0	11·0
	75	13·1	11·6	10·6
50	50	15·0	13·3	12·1
	55	14·5	12·9	11·7
	60	13·9	12·4	11·3
	65	13·3	12·0	10·9
	70	12·8	11·5	10·5
	75	12·3	11·0	10·1
55	55	13·6	12·4	11·3
	60	13·0	11·9	10·9
	65	12·4	11·3	10·5
	70	11·8	10·8	10·0
	75	11·3	10·3	9·5
60	60	12·2	11·2	10·5
	65	11·5	10·6	10·0
	70	10·9	10·1	9·5
	75	10·3	9·5	9·0
65	65	10·7	10·0	9·4
	70	10·0	9·4	8·9
	75	9·3	8·7	8·3
70	70	9·2	8·6	8·2
	75	8·4	7·9	7·6
75	75	7·6	7·2	6·9

IV. — VALUATION OF PROPERTY.

The valuations in which the architect is consulted are properly only those wherein buildings have been or may be erected; from which if he wander, the probability is that he will create difficulty for himself, tending to exhibit him as a pretender to knowledge not within the regular course of his occupation. The general principles, therefore, on which we propose to touch, are confined to the species of property above named, as distinguished from that in which the resident valuator near the spot in the different provinces is the best adviser, from the local knowledge he possesses. The auctioneers who with unblushing effrontery pretend to a knowledge of the value of property in the metropolis, are utterly incompetent to the duties they undertake, from an ignorance of the durability and cost of buildings, which can be attained by the practice and experience of the architect only.

Buildings may be so disadvantageously placed on their sites as to realise nothing like a proper interest on the money expended in their erection; and, indeed, so as altogether to destroy even the great value of the ground on which they are built. Thus, to place before the reader extreme cases, which generally best illustrate a subject, let him suppose a row of hovels built in Piccadilly, and a house like Apsley House placed in Wapping High Street. In both cases the productive value of the ground is destroyed, there being no inhabitants for such dwellings in the respective quarters of the town.

From this it must be evident that the value of town or city property, which consists principally of buildings, is divisible into two parts; namely, —

That arising from the value of the soil or site; and
That which arises from the value of the buildings placed upon it.

We will suppose for a house which is fairly let at a rent of 100*l.* per annum, no matter what the situation of it be, that it could be built for 1000*l.*, and that the proprietor or builder would be content with 7 per cent. for the outlay of his money, a rate by no means larger than he would be entitled to claim, seeing that the letting, after it is built, is a matter of speculation, and that loss of tenants and other casualties may temporarily deprive him of the interest of his capital. In this case, then, the rent of the mere building would be 70*l.*; and as the full rent assumed is 100*l.*,

100 − 70 = 30, which is manifestly the value of the ground or ground rent.

Thus in the cases of valuation of freeholds, wherein the gross rent can be accurately ascertained, there can be no difficulty in coming at the real value of the ground rent, because the building rent, or that arising from the expenditure of money on the soil, can be immediately ascertained by the architect, with the rate of interest on it which it is fit the builder should have. The remainder of the rent is that inseparably attached to the value of the soil, and belongs to the ground landlord.

The reason for thus separating the two rents is this: the ground rent, attached as it is to the soil, is imperishable. It is true that the value of ground is constantly fluctuating from the power of fashion over certain localities; but with this the valuator cannot deal. The changes are slow; and the Lord Shaftesbury in the time of Charles II. would have little thought it possible, when he placed his residence in Aldersgate Street, that his successors would have dwelt in a house in Grosvenor Square; neither, even five and twenty years ago, did it cross the mind of the then possessor of the Grosvenor property that the Five Fields at Chelsea contained a mine of wealth in the ground rents of Belgrave and Eaton Squares. Such are the mutations of property, with which the present question is not involved, unless the gift of foresight, in a degree not to be expected, be given to the valuator. The other portion of the value of house property is strictly the result of the perishable part of it, namely, the building itself; and this is limited by the durability of the building, which has great relation to the time it has already existed, and to the substantiality with which it has been constructed. The durability, then, or the number of years a building will continue to realise the rent, is the second ingredient in a valuation, and is a point upon which none but an experienced person can properly decide.

The rate of interest which the buyer is content to obtain in the investment of his money in buildings, or, in other words, in the purchase of the perishable annuity arising from the building, will necessarily vary with the value of money in the market. In the compensation cases under public improvements, wherein it is obligatory on the owner to part with his property, the *5* per cent. rate of the table is generally used, by which the buyer makes too little interest on the perishable part of the property. Few would be inclined to invest money in such property at so low a rate, for a rent which every year, from wear and tear, becomes less valuable. Individuals understanding the subject would scarcely be found to purchase, unless they could make at least 7 per cent. for this part of the capital. In the cases above mentioned, twenty-five years' purchase, that is, 4 per cent., is the usual price at which the ground rent is taken.

We will, having thus prepared the student, present an example of a valuation conducted on the principles named. Thus, suppose a building and the ground on which it stands to be together worth 150*l.* per annum, and that its durability is such that a purchaser may count on receiving that rent during a term of fifty years. We will suppose the house to stand upon a plot of ground 24 feet in frontage, and 60 feet in depth; that the size of the house is 24 feet by 40 feet, and that to build a similar one would cost 1440*l.*, which, at a rate of 7 per cent. upon the expenditure, would produce a building rent of 100*l.* 16*s.* per annum.

	£	*s.*	*d.*	£	*s.*	*d.*
Now the total rent being - - - - -	150	0	0			
The rent arising from the building itself - -	100	16	0			
The value of the mere ground must be - - -	49	4	0			
We therefore here have the imperishable part, viz. the ground, of the value of 49*l.* 4*s.* per annum, which, giving the purchaser 4 per cent. interest for his money, is twenty-five years' purchase for the fee-simple by the Fourth Table, that is - - - - - - -				1230	0	0
An annuity (from the building) of 100*l.* 16*s.*, to continue for fifty years, is, by the Fourth Table at 5 per cent., worth 18·256 years' purchase, that is - - - - - - - - - -				1840	0	11
The value of the old materials at the end of the term, if taken to be pulled down and sold for 150*l.*, will be that sum at the end of fifty years to be received at the present time, discounting at 5 per cent. from the Second Table ·1107 x 150 - - - - =				16	12	1
Total value of the freehold - - -				3086	13	0

In the above valuation the ground estimated by its frontage would be $\frac{49l.\ 4s.}{24\text{ feet}}=41s.$ per foot, and ground is usually let by the foot when demised for building.

The next case of valuation is that of a beneficial lease, in which the rent paid by the lessee is less than the actual value of the premises. The difference between them, therefore, is an annuity for the term of the lease, which is so much benefit to the lessee, and is estimated by the Fourth Table; thus,—

Suppose the actual value of given premises be - - - - -	£100
Rent reserved by the lessor - - - - - - -	50
Beneficial annuity belonging to the lessee - - - - - -	£50

If the term of the lease be twenty-one years, such is the length of the annuity, and the question stands as under:—

An annuity for twenty-one years, discounting at 5 per cent., is by the Fourth Table worth 12·8211 years' purchase, which multiplied by 50*l.* = - £641 1*s.*

It is to be observed that the annuities must be clear after the deduction of all outgoings which may be necessary to keep it unencumbered.

In the valuation of warehouses, the only safe method of coming at the value of a rental is by the quantity of goods or tonnage they will contain, after leaving proper gangways, and not overloading the floors. In corn warehouses, however, the grain being distributed over the surface of the floor, the squares of floor are taken to come at the contents. Goods warehoused are paid for to the warehouseman usually at a weekly or monthly rent; and it is commonly considered that the profit he should make ought to be one half of the rent he pays to the landlord, so that in fact two thirds of the actual rent realised goes to the proprietor, and the other third to the warehouseman or lessee. The following is a table of the space occupied by different goods:—

Of cork, there are - - - - -	149·333	cube feet in a ton.
Of fir - - - - -	65·163	—
Of indigo - - - - -	46·606	—
Of tallow - - - - -	38·046	—
Of gum - - - - -	24·683	—
Of brimstone - - - - -	19·801	—
Of whale oil - - - - -	38·818	—

The mean of the above is 38·853 cube feet to a ton; and, indeed, 40 feet is the usual allowance taken by warehousemen, 35 feet being that calculated in shipping.

Sugar in hogsheads will be found to be about 69 cube feet to the ton. Thus, a hogshead 3 ft. 6 in. high, 3 ft. 4 in. diameter at the ends, and 3 ft. 11 in. in the middle, weighs about 15¼ cwt.

The following are the usual dimensions and weights of tea in the chests, which, however, are not always uniform: —

	Dimensions.	Cube.	Weight.	Lbs. per Foot Cube.	Cube Feet in a Ton.
Congo -	1 10½ 1 8½ 1 4½	4·403	111 lbs.	25·21	88·87
Souchong	1 7½ 1 7½ 1 7	4·180	108 lbs.	25·84	86·70
Bohea -	2 9 1 10 1 8½	8·609	224 lbs.	26·02	86·09
Twankay	1 11½ 1 6 1 8	5·140	104 lbs.	20·23	110·70
Hyson -	1 6½ 1 6 1 9	4·048	80 lbs.	19·76	113·34
The means will be		5·276	- -	23·41	97·14

Wheat, taking the average weight of a Winchester bushel at 60 lbs., will give 48·13 cube feet to a ton.

In the valuation of leases held on lives, the operation, after bringing the rent to a clear annuity, is conbucted by means of the sixth, seventh, and eighth tables, as the case may require.

A
GLOSSARY OF TERMS USED BY ARCHITECTS;

ALSO

A LIST OF THE PRINCIPAL ARCHITECTS

OF ALL TIMES AND COUNTRIES, ALPHABETICALLY ARRANGED,

AND

A CATALOGUE OF THE MOST USEFUL WORKS ON ARCHITECTURE.

A.

Abaciscus. A word sometimes used as synonymous with abacus, but more correctly applied to a square compartment enclosing a part or the entire pattern or design of a Mosaic pavement.

Abacus. (Gr. Αϐαξ, a slab.) The upper member of the capital of a column, and serving as a crowning both to the capital and to the whole column. It is otherwise defined by some as a square table, list, or plinth in the upper part of the capitals of columns, especially of those of the Corinthian order, serving instead of a drip or corona to the capital, and supporting the nether face of the architrave, and the whole trabeation. In the Tuscan, Doric, and ancient Ionic orders, it is a flat square member, well enough resembling the original title; whence it is called by the French *tailloir*, that is, a trencher, and by the Italians *credenza*. In the richer orders it parts with its original form, the four sides or faces of it being arched or cut inwards, and ornamented in the middle of each face with a rose or other flower, a fish's tail, &c.; and in the Corinthian and Composite orders it is composed of an ovolo, a fillet, and a cavetto. The word is used by Scamozzi to signify a concave moulding in the capital of the Tuscan pedestal.

Abate, Nicholas. See Architects, list of, 240.

Abaton. (Gr. Αϐατον, an inaccessible place.) A building at Rhodes, mentioned by Vitruvius, lib. ii., entrance whereof was forbidden to all persons, because it contained a trophy and two bronze statues erected by Artemisia in memory of her triumph in surprising the city.

Abattoir. (Fr. Abattre, to knock down.) A building appropriated to the slaughtering of cattle. See p. 797.

Abbey. (Fr. Abbaïe.) Properly the building adjoining to or near a convent or monastery, for the residence of the head of the house (abbot or abbess). It is often used for the church attached to the establishment, as also for the buildings composing the whole establishment. In such establishments the church was usually grand, and splendidly decorated. They had a *refectory*, which was a large hall in which the monks or nuns had their meals; a *guest hall*, for the reception and entertainment of visitors; a *parlour* or *locutory*, where the brothers or sisters met for conversation; a *dormitory*, an *almonry*, wherefrom the alms of the abbey were distributed; a *library* and *museum*; a *prison* for the refractory, and *cells* for penance. The *sanctuary* was rather a precinct than a building, in which offenders were, under conditions, safe from the operation of the law. *Granges*, or farm buildings, and *abbatial* residences. *Schools* were usually attached for the education of youth, with separate accommodations for the scholars. A *singing school*, a *common room*, with a fire in it, for the brothers or sisters to warm themselves, no other fire being allowed, except in the apartments of the higher officers. A *mint*, for coining, and a room called an *exchequer*. The abbey was always provided with a *churchyard*, a *garden*, and a *bakehouse*. The *sacristy* contained the garments of the priests, and the vessels, &c.; *vestiaria* or wardrobes being assigned for the monks. Many of the ordinary duties of these persons were performed in the cloisters where they delivered their lectures.

Abele tree. A species of white poplar, enumerated among woods by Vitruvius (book ii.

chap. ix.) as being, in many situations, serviceable from its "toughness," and also from its colour and lightness fitting it for carvings.

Abreuvoir. (Fr.) A watering-place for horses. In masonry it is the joint between two stones, or the interstice to be filled up with mortar or cement, when either are to be used.

Absciss, or Abscissa. (Lat. Ab and Scindo.) A geometrical term, denoting a segment cut off from a straight line by an ordinate to a curve.

Absis. See Arsis.

Abstract. A term in general use among artificers, surveyors, &c. to signify the collecting together and arranging under a few distinct heads the various small quantities of different articles which have been employed in any work, and the affixing of a price to determinate portions of each, as per square, per foot, per pound, &c., for the purpose of more expeditiously and conveniently ascertaining the amount. See p. 620, *et seq.*

Abuse. A term applied to those practices in architecture which, arising from a desire of innovation, and often authorised by custom, tend to unfix the most established principles, and to corrupt the best forms, by the vicious way in which they are used. Palladio has given a chapter on them in his work. He reduces them to four principal ones: the first whereof is the introduction of brackets or modillions for supporting a weight; the second, the practice of breaking pediments so as to leave the centre part open; third, the great projection of cornices; and, fourth, the practice of rusticating columns. Had Palladio lived to a later day, he might have greatly increased his list of abuses, as Perrault has done in the following list: the first whereof is that of allowing columns and pilasters to penetrate one another, or be conjoined at the angles of a building. The second, that of coupling columns, which Perrault himself in the Louvre has made almost excusable; the third, that of enlarging the metopæ in the Doric order, for the purpose of accommodating them to the intercolumniations; the fourth, that of leaving out the tailloir in the inferior part of the modern Ionic capital; the fifth, that of running up an order through two or three stories, instead of decorating each story with its own order; the sixth, that of joining, contrary to the practice of the ancients, the plinth of the column to the cornice of the pedestal, by means of an inverted cavetto; the seventh, the use of architrave cornices; the eighth, that of breaking the entablature of an order over a column, &c. &c.

Abutment. (According to some, from the French *aboutir*, to *abut*, among whom the learned Spelman; but according to others, from the Saxon abutan, *about*.) The solid part of a pier from which the arch immediately springs. Abutments are artificial or natural: the former are usually formed of masonry or brickwork, and the latter are the rock or other solid materials on the banks of the river, in the case of a bridge, which receive the foot of the arch. It is obvious that they should be of sufficient solidity and strength to resist the thrust of the arch. See p. 401, *et seq.*, and Arch in this glossary.

Abuttals. The buttings or boundings of land.

Acanthus. (*Ακανθος*, a spine.) A spiny herbaceous plant found in various parts of the Levant. Its leaf is said by Vitruvius to have been the model on which the Grecian architects formed the leaves of the Corinthian capital. See p. 61.

Acer. (Celt. Ac, a point; Lat. Acer, sharp.) A genus of trees comprehending the maple and sycamore, the wood whereof is not of much value. That of the acer campestre furnishes the cabinet-makers with what they call bird's-eye maple.

Accesses. See Passage.

Accidental Point. In perspective, the point in which a straight line drawn from the eye parallel to another straight line cuts the perspective plane. It is the point wherein the representations of all straight lines parallel to the original straight line concur when produced. Its name is adopted to distinguish it from the principal point or point of view. See Perspective, p. 649, *et seq.*

Acoustics. (Gr. *Ακούω*, to hear.) The doctrine or theory of sounds, as applicable to buildings. See p. 801, *et seq.*, Theatre.

Acropolis. (Gr. *Ακρος* and Πολις, city.) The upper town or citadel of a Grecian city, usually the site of the original settlement, and chosen by the colonists for its natural strength. The most celebrated were those of Athens, Corinth, and Ithome, whereof the two latter were called the horns of the Peloponnesus, as though their possession could secure the submission of the whole peninsula.

Acroteria. (Gr. *Ακρωτηριον*, the extremity of anything.) The pedestals, often without base or cornice, placed on the centre and sides of pediments for the reception of figures. Vitruvius says that the lateral acroteria ought to be half the height of the tympanum, and the apex acroterium should be an eighth part more. No regular proportion, however, is observable in Grecian buildings.

The word acroterium is applied to the ridge of a building; it has also been used to signify the statues on the pedestals; but it is only to these latter that it is strictly applicable. The word has moreover been given to the small pieces of wall in balustrades, between the pedestal and the balusters, and again for the pinnacles or other ornaments which stand in ranges on the horizontal copings or parapets of buildings.

Acute-angled Triangle. A triangle having all its angles acute. Every triangle has at least two acute angles.

Acute Angle. A term used in geometry to denote an angle less than 90°, that is, less than a right angle.

Adam, Robert. See Architects, list of, 302.

Adams, Robert. See Architects, list of, 244.

Adhesion (Lat. Adhæreo.) A term in physics denoting the force with which different bodies remain attached to each other when brought into contact. It must not be confounded with cohesion, which is the force that unites the particles of a homogeneous body with each other. The following is an account of some experiments recorded in the *Technical Repository* for 1824. “ The insertion of a nail is accomplished by destroying the cohesion of the wood, its extraction by overcoming the force of adhesion and friction. We will consider it here solely as a case of adhesion. Fine sprigs, of which 4560 weighed one pound, $\frac{44}{100}$ of an inch long, forced four tenths of an inch into dry Christiana deals at right angles to the fibre, required a force of 22 lbs. to extract them. The same description of nail having 3200 in the pound, $\frac{53}{100}$ of an inch long, and forced $\frac{44}{100}$ of an inch into the same kind of wood, required 37 lbs. to extract it. Threepenny brads, 618 to the pound weight, one and a quarter inch long, forced half an inch into the wood, required a force of 72 lbs. to draw them out. Fivepenny nails, 139 to the pound weight, two inches long, and forced one inch and a half into the wood, required a force of 170 lbs. to extract them. The same kind of nail forced one inch and a half into the wood required 327 lbs. to draw it out. In this last experiment the nail was forced into the wood by a hammer of cast iron weighing 627 lbs. falling from a height of twelve inches, four blows of which were necessary to force the nail an inch and a half into the wood. It required a pressure of 400 lbs. to force the nail to the same depth. A sixpenny nail driven one inch into dry elm across the grain or fibres required 327 lbs. to draw it out by direct force; driven endwise into dry elm, or parallel with the grain, it required only 257 lbs. to extract it. The same sort of nail driven into dry Christiana deal was extracted by a force equal to 257 lbs., and by one of 87 lbs. from a depth of an inch. The adhesion, therefore, of a nail driven into elm across the grain, or at right angles to the fibres of the wood, is greater than when it is driven with the grain, or parallel with the fibres, in the proportion of 100 to 78, or 4 to 3. And under the same circumstances, in dry Christiana deal, as 100 to 46, or nearly 2 to 1. The comparative adhesion of nails in elm and deal is between 2 and 3 to 1. To extract a sixpenny nail driven one inch into green sycamore required 312 lbs.; from dry oak, 507 lbs.; and from dry beach, 667 lbs. A common screw of one fifth of an inch had an adhesion about three times as great as that of a sixpenny nail. A common sixpenny nail driven two inches into dry oak would require more than half a ton to extract it by pressure.”

Adit (Lat. Adeo), or **Aditus.** The approach or entrance to a building, &c. Among the ancients the *aditus theatri*, or adits of a theatre, were doorways opening on to the *stairs*, by which persons entered the theatre from the outer *portico*, and thence descended into the seats. Upon the same principle were the adits of a circus.

Adjacent Angle, in geometry, is an angle immediately contiguous to another, so that one side is common to both angles. This expression is more particularly applied to denote that the two angles have not only one side in common, but likewise that the other two sides form one straight line.

Adytum. (Gr. Ἄδυτον, a recess.) The secret dark chamber in a temple to which none but the priests had access, and from which the oracles were delivered. Seneca, in his tragedy of Thyestes says, —

> “ Hinc orantibus
> Responsa dantur certa, dum ingenti sono
> Laxantur adyto fata.”

Among the Egyptians the *secos* was the same thing, and is described by Strabo. The only well-preserved ancient adytum that has come to our knowledge is in the little temple at Pompeii; it is raised some steps above the level of the temple itself, and is without light.

Adze, or **Addice.** An edged tool used to chip surfaces in an horizontal direction, the axe being employed to chop materials in vertical positions. The blade, which is of iron, forms a small portion of a cylindric surface in both its sides, and has a wooden handle fixed into a socket at one of its extremities, in a radial direction, while the other extremity, parallel to the axis of the cylinder, and therefore at right angles to the handle, is edged with steel, and ground sharp from the concave side. The adze is chiefly employed for taking off thin chips from timber or boards, and for paring away irregularities at which the axe cannot come. It is also used in most joinings of carpentry, particularly when notched upon one another, scarfings, thicknesses of flooring boards opposite to the joints, &c.

Ælfric. See Architects, list of, 76.

Aerial Perspective. The relative apparent recession of objects from the foreground, owing to the quantity of air interposed between them and the spectator. It accompanies the recession of the perspective lines.

Æsthetics. (Gr. *Αισθητικος*, having the power of perception by means of the senses.) It is in the fine arts that science which derives the first principles from the effect which certain combinations have on the mind as connected with nature and right reason. See p. 673.

Ætherius. See Architects, list of, 60.

Ætiaioi. (Gr. *Αετος*, an eagle.) The name given by the Greek architects to the slabs forming the face of the tympanum of a pediment. This word occurs in the Athenian inscription now in the British Museum, brought to England by Dr. Chandler, and relating to the survey of some temple at Athens.

Ætoma, or Ætos. (Gr. *Αετος*.) A name given by the Greek architects to the tympanum of a pediment. It seems derived from the custom of decorating the apex or ridge of the roof with figures of eagles, and that the name thence first given to the ridge was afterwards transferred to the pediment itself.

Agamedes. See Architects, list of, 3.

Agaptos. See Architects, list of, 10.

Agnolo d', Baccio. See Architects, list of, 206.

Agnolo Gabriello. See Architects, list of, 171.

Agostino and Angelo, of Siena. See Architects, list of, 131.

Agricola. See Architects, list of, 59.

Air Drains, or Dry Areas. Cavities between the external walls of a building protected by a wall towards the earth, which is thus prevented from lying against the said walls and creating damp. They may be made with the walls battering against the ground, and covered over with paving stones, or with their walls nearly perpendicular, and arched on the top; the bottoms should be paved, and they should be well ventilated.

Air Holes. Holes made for admitting air to ventilate apartments, also for introducing it among the timbers of floors and roofs for the prevention or destruction of the dry rot.

Air Trap. A trap immersed various ways in water to prevent foul air rising from sewers or drains.

Ajutage. (Fr.). Part of the apparatus of an artificial fountain, being a sort of *jet d'eau*, or kind of tube fitted to the mouth or aperture of a vessel, through which the water is to be played, and by it determined into the form to be given to it.

Aisle, or Ala. (Lat. Ala.) A term chiefly used by the English architect to signify the side subdivisions in a church, usually separated from the nave or centre division by pillars or columns; but among different nations, as applied to architecture, it bears different significations. We are told by Strabo that among the Egyptians the alæ of the temple were the two walls that enclosed the two sides of the pronaos, and of the same height as the temple itself. The walls, he observes, from above ground, were a little farther apart than the foundations of the temple, but as they rose, were built with an inclination to each other. We do not, however, clearly understand the passage, which puzzled Pocock as much as it has ourselves. The Greek alæ, called *ptera*, were the colonnades which surrounded the cell of the temple, the monopteros temple being the only species which had columns without a wall behind them. The peripteral had one tier of columns round the cell, the dipteral two, and the pseudo or false dipteral, invented by Hermogenes, was that in which the ala was single, but occupied the same space on the sides of the cell as the dipteral, though one of the tiers of columns was left out. Thus, by metaphor, the columns were called the alæ or wings of the temple. The term is also applied to the sides of a building which are subordinate to the principal and central division, and are vulgarly called wings. In Gothic as well as many modern churches the breadth is divided into three or five parts, by two or by four rows of pillars running parallel to the sides; and as one or other is the case, the church is said to be a three-aisled or five-aisled fabric. The middle aisle is called the nave or chief aisle, and the penthouse, which joins to each side of the main structure containing the aisles, is called a wing. In Great Britain no instance occurs of a five-aisled church, except a building at the west end of the cathedral at Durham. On the Continent there are many such buildings, among which is the cathedral at Milan. It is somewhat remarkable that in Westminster Abbey and in Redcliffe Church at Bristol the aisles are continued on each side of the transept, and in Salisbury Cathedral on one side only, a circumstance not met with in any other churches in this country.

Alabaster. A white semi-transparent variety of gypsum or sulphate of lime, a mineral of common occurrence, and used for various ornamental purposes. It was much used formerly for monuments in churches and the like.

Albarium Opus. (Lat.) In ancient Roman architecture a term imagined by some to have been nothing more than a species of whitewash applied to walls, but, as we think, incorrectly. In the passage of the tenth chapter of the fifth book of Vitruvius, where he recommends the use of the albarium opus for the ceilings of baths, he allows *tectorium opus* as a substitute; so that we think it was a species of stucco. Its employment at the baths of Agrippa, knowing as we do the extent to which luxury was carried in the baths of the ancients, seems to prove it a superior sort of stucco, and it is by no means improbable that it was susceptible of a high polish.

Albert. See Architects, list of, 69.

Alberti, Aristotele. See Architects, list of, 180.

———, Leo Batt. See Architects, list of, 162.

Alcock. See Architects, list of, 169.

Alcove. (Alcoba, Sp.; Elcant, Arab., a sleeping chamber.) That part of a sleeping chamber wherein the bed is placed. The use of alcoves, though not by that name, is ancient. They were frequently designed in the form of a niche; such, for instance, as those that Winkelman notices at Hadrian's villa at Tivoli, of which sort are some at Pompeii. They were often formed by enclosures or balustrades, of various heights, and by means of draperies the part was separated from the large chamber whereof it was a part. Some idea may be formed of it from many of the ancient bassi relievi, especially from the celebrated one known by the name of the *Nozze Aldobrandini*. In modern works this part of a room differs according to the rank and taste of the proprietor. In England it is rarely introduced, but in France and Italy it often forms a beautiful feature in the apartments of palaces.

Alder. (Ang. Sax. Ellarn.) A tree belonging to the order Betulaceæ. See page 486.

Aldrich. See Architects, list of, 268.

Aldun. See Architects, list of, 79.

Aleotti. See Architects, list of, 253.

Alessi. See Architects, list of, 215.

Aleatorium. In ancient Roman architecture, a room in which games at dice were played.

Alexander. See Architects, list of, 90.

Algardi. See Architects, list of, 256.

Alipterion. In ancient Roman architecture, a room used by the bathers for anointing themselves.

Alkoranes. In Eastern architecture, high slender towers attached to mosques, and surrounded with balconies, in which the priests recite aloud at stated times prayers from the Koran, and announce the hours of devotion to worshippers. They much embellish the mosques, and are often very fantastical in form.

Alley. (Fr. Allée.) An aisle, or any part of a church left open for access to another part. In towns, a passage narrower than a lane. A walk in a garden.

Almehrab. A niche in the mosques of the Mahometans which points towards the *Kebla*, or temple of Mecca, to which their religion directs them to bow their face in praying.

Almonry. Properly a closet or repository for the reception of broken victuals set apart as alms for the poor, but more generally used to denote a house near the church in abbeys or their gates, provided with various offices for distributing the alms of the convent and for the dwelling of the almoner.

Almshouse. A house devoted to the reception and support of the poor, generally endowed for a particular description of persons.

Aloisius. See Architects, list of, 56.

Alonso. See Architects, list of, 196.

Altar. (Lat. Altare.) A sort of pedestal whereon sacrifice was offered. According to Servius there was among the ancients a difference between the *ara* and *altare*, the latter being raised upon a substruction, and used only in the service of the celestial and superior divinities, whereas the former was merely on the ground, and appropriated to the service of the terrestrial gods. Altars to the infernal gods were made by excavation, and termed *scrobiculi*. Some authors have maintained that the ara was the altar before which prayers were uttered, and that the altare was used for sacrifices only. There is however from ancient authors no appearance of such distinctions, but that the words were used indiscriminately. The earliest altars were square polished stones, on which were placed the offerings to the gods. Whilst the sacrifice consisted only of libations, perfumes, and offerings of that nature, the altar was small, and even portable; when man, however, began to consider he was honouring the divinity by an offering of blood, the altar necessarily expanded in dimensions. Different forms of it were adopted, according to the nature of the sacrifice, and on it the throat of the victim was cut and the flesh burnt. Of this sort is the circular altar of the Villa Pamphili at Rome, one of the largest and most elegant of the class. On it appears the cavity for holding the fire, and the grooves for carrying off the blood. The varieties of altars were suitable in form, ornament, and situation to the service to which they were appropriated: some, as we have already observed, being for sacrifices of blood, others for receiving offerings and the sacred vessels; some for burning incense, others for receiving libations. Many were set up as mere monuments of the piety of a devotee, whilst others were raised to perpetuate some great event. They served for adjuration as well as for an asylum to the unfortunate and evil doer. In form they varied from square to oblong, and from triangular to circular. Those of metal were commonly tripodial. When of brick or stone their plan is generally square. According to Pausanius they were occasionally made of wood. They do not appear to have been of any regular standard height, for they are sometimes found on bassi relievi reaching but little above a man's knee, whereas in others they appear to reach his middle; but it seems that in proportion to its diameter the circular altar was generally the highest. Vitruvius says that they should not be so high as to intercept the statues of the gods, and he gives the relative heights of those used for different divinities. Thus, he says, those of Jupiter and the celestial gods are to be the highest; next, those of Vesta and the terrestrial gods; those of the sea gods are to be a little lower, and so on. On festivals they were decorated with such flowers and leaves as were sacred to the particular divinity. But besides this casual decoration, the ancient altars furnish us with some of the most elegant bassi rilievi and foliage ornaments that are known. According to Vitruvius, their fronts were directed towards the east, though very frequently but little regard was paid to their position, as they were occasionally placed under the peristyle of a temple, and not unfrequently in the open air. In the larger temples were often three different altars. The first was in the most sacred part, in front of the statue of the god; the second before the door of the temple; and the third (called *ancalabris*) was portable, and on it the offerings and sacred vessels were placed.

The altars of the Catholic church are either attached or isolated. The former generally stand against a wall, and are so decorated as to appear quite independent of it. The decorations are either of painting or sculpture, or both. The isolated altar has no sort of connection with any part either of the building or of its decorations. The high altar is always isolated, whether placed at the end of the church or in its centre. Whatever the situation of the high altar, it should be grand and simple: it should be raised on a platform, with steps on every side. The table itself is usually in the form of an antique sarcophagus. The altar of the Protestant churches of England is generally only an oak table, covered with a white cloth, and but little ornamented either above or on the sides. In country churches we sometimes find superadded as an ornament, to show, we suppose, that painting may be tolerated in Protestant worship, the figures

> " Of Moses and Aaron stuck close by the wall,
> To hold the commandments for fear they should fall."

The fact is, the Church of England is so overawed by sectaries, that she is afraid of doing anything congenial to the feelings of a polished mind as respects the decoration of her churches, which are in the new examples built by the commissioners more than ever stript of all elegant accompaniments; a practice which turns our churches into barns rather than temples of the Most High.

The altars of the Greek church, though in other respects the religion vies in splendour with the Romish church, are destitute of painted or sculptured ornament; and in Calvinistic churches the name as well as the uses of an altar are unknown either as an appendage or a decoration.

Altar-piece. The entire decorations of an altar.

Altar Screen. The back of an altar, or the partition by which the choir is separated from the presbytery and Lady chapel. The date of its introduction into English churches we believe to have been about the close of the thirteenth century. It is generally of stone, and composed of the richest tabernacle work, of niches, finials, and pedestals, supporting statues of the tutelary saints. Those to the high altars of Winchester Cathedral, of St. Alban's Abbey, and of New College, are fine examples. Many were destroyed at the Reformation, or filled up with plaster and covered with wainscot. In all altar screens a door is placed on each side for the officiating priests, whose vestments were deposited in an apartment behind the altar screen.

Alto Rilievo. See Rilievo.

Alypius. See Architects, list of, 53.

Ambitus. A space which surrounded a tomb, and was held sacred. In descriptions of subterranean tombs, it denoted a small niche made in the wall for the reception of an urn or body. When the corpse was placed in it, to the mouth of the niche a slab was fixed, so fitted and cemented as to prevent noisome effluvia. The slabs were sometimes inscribed with the name and quality of the party. If they received an urn, either upon that or over the niche the inscription was placed. Much decoration was occasionally used in the recesses themselves.

Ambo. (Gr. ἄμβων.) The elevated place or pulpit in the early Christian churches, which, according to Ciampini, fell into disuse about the beginning of the fourteenth century.

The last erected ambo in Rome is supposed to have been that of S. Pancrazio, on which appears the date of 1249. It was an oblong enclosure, with steps usually at the two ends. Two ambones are described by Eustace in the cathedral at Salerno. They are placed on each side of the nave before the steps of the chancel. They are both of marble, and the largest is covered with mosaic and supported by twelve Corinthian granite columns.

Ambulatory. (Lat.) A sheltered place for exercise in walking; a cloister; a gallery.

Ambulatio. (Lat.) See Pteroma.

Ammanati. See Architects, list of, 239.

Amphiprostyle. (Gr. αμφι, both or double, προ, before, στυλος, a column.) A term applied to a temple having a portico or porch in the rear as well as in the front, but without columns at the sides. This species of temple never exceeded the use of four columns in the front and four in the rear. It differed from the temple in *antis*, in having columns instead of antæ at the angles of the portico. See Temple.

Amphitheatre. (Gr. αμφι, about, and θεατρον, a theatre.) An edifice formed by the junction of two theatres at the proscenium, so as to have seats all round the periphery, a contrivance by which all the spectators, being ranged about on seats rising the one above the other, saw equally well what passed on the arena or space enclosed by the lowest range of seats, whose wall towards the arena was called the *podium*. The origin of the amphitheatre seems to have been among the Etruscans, to whom also are attributed the first exhibitions of gladiatorial fights. It was from this people that the Romans acquired a taste for such shows, which they communicated to every nation which became subject to their dominion. Athenæus says, "Romani ubi primum ludos facere cœperunt, huic asciti artifices ab Etruscis civitatibus fuerunt, sero autem ludi omnes qui nunc a Romanis celebrari solent sunt instituti." Lib. iv. c. 17. The most extraordinary edifice remaining in Rome, we may indeed say in the world, is the amphitheatre generally called the Coliseum. It was commenced by Vespatian, and completed by Titus his son. Words are inadequate to convey a satisfactory idea of its stupendous and gigantic dimensions. Ammianus says that it was painful to the eye to scan its summit: "ad cujus summitatem ægrè visio humana conscendit." Martial, in one of his epigrams, says,

> "Omnis Cæsareo cedat labor amphitheatro,
> Unum pro annetis fama loquatur opus."

The greater axis of the ellipsis on which it is planned is about 627 feet, and the lesser 520 feet, the height of the outer wall about 166 feet, such wall being decorated by the Doric, Ionic, and Corinthian Orders, and pierced with arcades between the columns. Covering five English acres and a quarter, it had seats for 87,000 spectators with standing room for 22,000 others. It has suffered much from having been used actually as a quarry for many of the modern edifices of the city; but in the present day its preservation is strictly attended to by the papal government. A description of this building has been given in p. 94, *et seq.* Besides the Coliseum, there were three other amphitheatres in Rome: the Amphitheatrum Castrense, on the Esquiline, built probably by Tiberius; that of Statilius Taurus, and that built by Trajan in the Campus Martius. The other principal amphitheatres were those of Otricoli on the Garigliano, of brick; Puzzuoli, Capua, Verona, at the foot of Monte Casino, Pæstum, Syracuse, Agrigentum, Catanea, Argos, Corinth, Pola in Istria (see *fig.* 127.), Hipella in Spain, Nismes, Arles, Frejus, Saintes, and Autun. This last has four stories, in that respect like the Coliseum. That which remains in the most perfect condition is at Verona; its age has not been accurately determined, some placing it in the age of Augustus, and others in that of Maximian; of these, Maffei thinks the first date too early, and the latter too late. The silence of Pliny upon it seems to place it after the time of his writing. In the reign of Gallienus, it was not only built, but began to suffer from dilapidation, for many of the stones belonging to it are found in the walls of Verona, which walls were erected in the time of that emperor. Many of these were keystones, and the numbers cut upon them still remain. From the silence of authors that it was the work of any of the emperors, it seems probable that, like that at Capua, it was erected at the expense of the citizens. The length is about 514 feet, and the breadth about 410; the long diameter of the arena 242 feet, the short diameter 147 feet. The audience part or *visorium* contained forty-seven tiers of seats, and the building was capable of containing about 22,000 seated spectators. In the profile of the walls of this amphitheatre the diminution in thickness upwards is made on the inside, which is also the case in that at Pola. In the Coliseum, the diminution is on the outside. The amphitheatre at Nismes contained about 17,000 persons, and was about 400 feet in length and 320 feet in breadth.

The first amphitheatres, as we learn from Pliny, were constructed of wood, and usually placed in the Campus Martius, or in some place out of the city. Accidents occurring from their insecurity, they were abandoned for the more substantial species of fabric whereof we have been speaking. The first person who is said to have erected an amphitheatre in Rome was Caius Scribonius Curio, on the occasion of the games he gave to the people at the funeral obsequies of his father. Determined to surpass all that had hitherto been seen, he constructed two theatres of wood, back to back, which, after the theatrical representations had been finished, were turned round with the spectators in them, leaving the stages and scenery behind. By their opposite junction, they formed a perfect amphitheatre, in which the people were gratified with a show of gladiators.

The part in which the gladiators fought was called the *arena*, from being usually covered with sand to absorb the blood spilt in the conflicts, for which it was used. It was encompassed by a wall called the *podium*, fifteen or sixteen feet high, immediately round which sat the senators and ambassadors. As in the theatres, the seats rose at the back of each other; fourteen rows back from the podium all round being allotted to the equites, and the remainder to the public generally, who sat on the bare stone, cushions being provided for the senators and equites. Though at most times open to the sky, there were contrivances for covering the whole space with an awning. The avenues by which the people entered and retired were many in number, and were called *vomitoria*. The reader who wishes for further information on this subject may consult with advantage Maffei, *Degli Amfiteatri*, and the section on amphitheatres in his excellent and learned work, *Verona illustrata*.

ANAMORPHOSIS. (Gr. *ανα*, backward, and *μορφη*, form.) A term employed in perspective to denote a drawing executed in such a manner that when viewed in the common way it presents a confused and distorted image of the thing represented, or an image of something entirely different; but when viewed from a particular point, or as reflected by a curved mirror, or through a polyhedron, it recovers its proportions and presents a distinct representation of the object.

ANCHOR. In decoration, an ornament shaped similarly to an anchor or arrow head. It is used with the egg ornament (see page 684. *fig*. 86.) to decorate or enrich mouldings. By some it is called a tongue, from its supposed resemblance to the forked tongue of a serpent. It is used in all the orders, but only applied to the moulding called the echinus or quarter round.

ANCONES. (Gr. *αγκων*, the joint of the elbow.) The trusses or consoles sometimes employed in the dressings or antepagmenta of apertures, serving as an apparent support to the cornice of them at the flanks. In ancient doors the ancones were sometimes broader at the top than at the bottom, and were not in contact with the flanks of the architrave, but situated a small distance from them, the ancones being still further removed. The term is also used to signify the corners or quoins of walls, cross beams, or rafters.

ANDREA DI PISA. See ARCHITECTS, list of, 130.

ANDRON. (Gr. *ανηρ*.) In ancient architecture, the apartment appropriated to the reception of the male branches of the establishment, and always in the lower part of the house, the *gynæcia*, or women's apartments, being in the upper part.

ANDRONICUS. See AACHITECTS, list of, 23.

ANDROUET DU CERCEAU. See ARCHITECTS, list of, 246.

ANGLE. (Lat. Angulus.) The mutual inclination of two lines meeting in a point, called indifferently the angular point, vertex, or point of concourse: the two lines are called legs. See GEOMETRY, page 306.

ANGLE BAR. In joinery, the upright bar at the angle of a polygonal window.

ANGLE BEAD, or STAFF BEAD. A vertical bead, commonly of wood, fixed to an exterior angle and flush with the intended surface of the plaster on both sides, for the purpose of securing the angle against accident, serving also as a guide for floating the plaster. The section of these beads is about three quarters of a circle, with a projecting part from the other quarter, by means whereof they are made fast to the wood bricks, plugging, or bond timbers. Angle beads of wood round the intradosses of circular arches are difficult to bend without cutting or steaming them. The former has a very unsightly appearance, and the latter method is at once inconvenient and troublesome. The plaster itself is the best material in this case, and at the height generally placed will be out of the reach of accident. In good finishings corner beads which are unsightly should not be used, but the plaster should be well guaged and brought to an arris.

ANGLE BRACE. In carpentry, a piece of timber fixed to the two extremities of a piece of quadrangular framing, making it partake of the form of an octagon. This piece is also called an *angle tie* and a *diagonal tie*. By the use of this piece wall plates are frequently braced. In constructing a well hole of a circular section through a roof or floor for a skylight, &c. the framing is first made in a quadrangular form; braces are then fixed opposite to each angle, and the aperture becomes an octagon; finally, pieces are fixed at each angle of the octagon, meeting each other in the middle of its sides, so as to transform the section of the aperture into a circle.

ANGLE BRACKET. A bracket placed in the vertex of an angle, and not at right angles with the sides. See BRACKETING.

ANGLE CAPITAL. In ancient Greek architecture, the Ionic capitals used to the flank columns which have one of their volutes placed at an angle of 135° with the planes of the front and returning frieze. As an example may be given the angle capitals of the temple of Minerva Polias at Athens. This term is also applied to the modern Ionic capital, in which the whole of the four volutes have an angular direction.

Angle Chimney. A chimney placed in the angle of a room.

Angle Modillion. A modillion placed in a direction parallel to a diagonal drawn through a cornice at its mitring. It is an abuse seen only in the buildings erected during the decline of Roman architecture, as in the ruins of Balbec and Palmyra, and in the palace of the Emperor Dioclesian at Spalatro.

Angle of Vision. (See Perspective, p. 649, *et seq.*) The angle under which an object or objects are seen, and upon which their apparent magnitudes depend. In practical perspective it should not exceed sixty degrees.

Angle of a Wall. The angle contained by the vertical planes of two walls which form the angle of the building. The term is sometimes used to denote the line in which the two sides of the angle meet, which by workmen is commonly called the *arris:* the arris however is not the angle, but the line of concourse formed by the two sides or planes which contain the angle.

Angle Rafter. The piece of timber in a hipped roof placed in the line of concourse of the two inclined planes forming the hip. It is more often called a hip rafter. See Hip and Carpentry, page 548.

Angle Rib. A piece of timber of a curved form placed between those two parts of a coved or arched ceiling or vault which form an angle with each other so as to range with the common ribs on each side or return part.

Angle Staff. See Angle Bead.

Angle Stones. A term used by some authors to denote *quoins.*

Angle Tie. See Angle Brace.

Angular Capital. See Capital.

Annuities. See p. 856, *et seq.*

Annular Mouldings. Generally those having vertical sides and horizontal circular sections.

Annular Vault. A vault springing from two walls each circular on the plan; such as that in the temple of Bacchus at Rome.

Annulet. (Lat. Annulus.) A small fillet whose horizontal section is circular. The neck or under side of the Doric capital is decorated with these thin fillets, listels, or bands, whose number varies in different examples. Thus in the Doric of the theatre of Marcellus there are three, whilst in the great temple at Pæstum they are four in number, and in other cases as many as five are used.

Anta, æ, plur. (Lat. Anta.) The joints or square posts supporting the lintels of doors. The term antæ we think only applicable to pilasters or pillars attached to a wall, though some authors, as Perault, have thought otherwise. Vitruvius calls square pilasters when insulated *parastatæ.* There are three kinds of antæ: those of porches or jamb ornaments; angular antæ, being such as show two faces on the walls of a temple; and those on the longitudinal walls of its cell. Antæ are only found in temples as wings to the ends of the walls of the pronaos to give a finish to the terminations the ends of the walls would otherwise present. It might have been this view which led the Greeks to treat them rather as distinct objects than to assimilate their finishings to those of columns. Considered as pilasters, the reader is referred to p. 735, *et seq.*, where the diminutions and capitals are fully considered. The latter were never made by the Greeks like those of the accompanying columns. The pilasters in Roman architecture differ only from the column in being square instead of round. A rule in the use of antæ was, that their projection should always be equal to that at least of the mouldings used on them. Some beautiful examples of antæ capitals exist in the temple of Minerva Polias and the temple of Apollo Didymæus in Ionia.

Ante-chamber or **Ante-room.** An apartment through which access is obtained to another chamber or room. One in which servants wait and strangers are detained till the person to be spoken with is at leisure. In the distribution of many houses the peculiarity of the plan forces upon the architect the introduction of ante-rooms: in most cases, indeed, they add both elegance and dignity to a design.

Antepagmenta. (Lat.) In ancient architecture, the jambs or moulded architraves of a door. The lintel returning at the ends with similar mouldings down upon the antepagmenta was called supercilium.

Anteraides. In ancient architecture, buttresses or counterforts for the support of a wall. The Italians call them *speroni* (spurs).

Anthemius. See Architects, list of, 61.

Ante-Cour. A French term, sometimes however used by English authors. It is the approach to the principal court of a house, and very frequently serves for communication with the kitchen, cellar, stables, &c.

Anticum. (Lat.) A porch to a front door, as distinguished from posticum, which is the porch to a door in the rear of a building. It was the space also between the front columns of the portico and the wall of the cellar. The word has been sometimes improperly used for *anta*.

Antifixæ. (Lat. anti and figo.) The ornaments of lions' and other heads below the eaves of a temple, through perforations in which, usually at the mouth, the water is cast away from the eaves. By some this term is used to denote the upright ornaments above the eaves in ancient architecture, which concealed the ends of the *harmi* or joint tiles.

Antique. A term applied to pieces of ancient art by the Greeks and Romans of the classical age.

Antiquarium. Among the ancients an apartment or cabinet in which they kept their ancient books and vases.

Antistates. See Architects, list of, 15.

Antoninus. See Architects, list of, 50.

Antonio, Fiorentino. See Architects, list of, 228.

Antoine. See Architects, list of, 306.

Apartment. (Lat. partimentum.) A space enclosed by walls and a ceiling, which latter distinguishes it from a court or area. The distribution of apartments of a building has already been treated of in this work. See p. 771, *et seq.*

Aperture. (Lat. aperio.) An opening through any body. In a wall it has usually three straight sides, two whereof are perpendicular to the horizon, and the third parallel to it, connecting the lower ends of the vertical sides. The materials forming the vertical sides are called *jambs*, and the lower level side is called the *sill*, and the upper part the *head*. This last is either a curved or flat arch. Apertures are made for entrance, light, or ornament. In Greek and Egyptian architecture, but especially in the latter, the jambs incline towards each other. Sometimes apertures are made circular, elliptical, or portions of those figures. "Apertures," says Sir Henry Wotton, "are inlets for air and light; they should be as few in number, and as moderate in dimensions, as may possibly consist with other due respects; for, in a word, all opening are weakenings. They should not approach too near the angles of the walls; for it were indeed a most essential solecism to weaken that part which must strengthen all the rest."

Apiary. (Lat. apis.) A place for keeping beehives. Sometimes this is a small house with openings for the bees in front, and a door behind, which is kept locked for security. Sometimes it is an area wherein each particular beehive is chained down to a post and padlocked.

Apodyterium. (*ἀποδύεσθαι*, Gr., to strip oneself.) The apartment at the entrance of the ancient baths, or in the Palæstra, where a person took off his dress, whether for bathing or gymnastic exercises. In the baths of Nero, these apartments were small, but in those of Caracalla the apodyterium was a magnificent room with columns and other decorations.

Apophyge. (Gr., signifying flight.) That part of a column between the upper fillet or amulet on the base and the cylindrical part of the shaft of a column, usually moulded into a hollow or cavetto, out of which the column seems as it were to fly or escape upwards. The French call it *congé*, as it were, leave to go.

Apollodorus. See Architects, list of, 47.

Apotheca. (Gr.) A storehouse or cellar in which the ancient Greeks deposited their oil, wine, and the like.

Apron, or Pitching Piece. An horizontal piece of timber, in wooden double-flighted stairs, for supporting the carriage pieces or rough strings and joistings in the half spaces or landings. The apron pieces should be firmly wedged into the wall. See Staircases, p. 575, *et seq.*

Apsis, or Absis. (Gr., signifying an arch.) A term in ecclesiastical architecture, denoting that part of the church wherein the clergy was seated or the altar placed. It was so called from being usually domed or vaulted, and not, as Isidorus imagines, from being the lightest part (apta). The apsis was either circular or polygonal, and domed over; it consisted of two parts, the altar and the presbytery or sanctuary. At the middle of the semicircle was the throne of the bishop, and at the centre of the diameter was placed the altar, towards the nave, from which it was separated by an open balustrade or railing. On the altar was placed the ciborium and cup. The throne of the bishop having been anciently called by this name, some have thought that thence this part of the edifice derived its name; but the converse is the fact. The *apsis gradata* implied more particularly the bishop's throne being raised by steps above the ordinary stalls. This was sometimes called *exedra*, and in later times *tribune*.

Aqueduct. (Lat. aquæ ductus.) A conduit or channel for conveying water from one place to another, more particularly applied to structures for the purpose of conveying the water of distant springs across valleys, for the supply of large cities. The largest and most magnificent aqueducts with the existence of which we are acquainted were constructed by the Romans, and many of their ruins in Italy and other countries of Europe still attest the power and industry of that extraordinary nation. The most ancient was that of Appius Claudius, which was erected in the 442d year of the city, and conveyed the Aqua Appia to Rome, from a distance of 11,190 Roman paces (a pace being 58·219 English inches), and was carried along the ground, or by subterranean lines, about 11,000 paces, about 190 of which were erected on arches. The next, in order of time, was the Anio Vetus, begun by M. Curius Dentatus, about the year of Rome 481. The water was collected from the springs about Tivoli; it was about 43,000 paces in length. In the 608th year of the city, the works of the Anio Vetus and Aqua Appia had fallen into decay, and much of the water had been fraudulently abstracted by individuals, the prætor Martius was therefore empowered to take measures for increasing the supply. The result of this was the Aqua Martia, the most wholesome water with which Rome was supplied. It was brought from the neighbourhood of Subiaco, twenty miles above Tivoli, and was 61,710 Roman paces (about 61 miles), whereof 7463 paces were above ground, and the remainder under ground. A length of 463 paces, where it crossed brook and valleys, was supported on arches. To supply this in dry seasons, was conducted into it another stream of equal goodness by an aqueduct 800 paces long. About nineteen years after this was completed, the Aqua Tepula was brought in, supplied also from the Anio; but not more than 2000 paces in length. In the reign of Augustus, Agrippa collected some more springs into the Aqua Tepula, but the latter water flowing in a separate channel, it preserved its name. This was 15,426 paces long, 7000 above ground, and the remainder of the length on arcades. To this was given by Agrippa the name of Aqua Julia. In the year 719 of the city, Agrippa restored the dilapidated aqueducts of Appius, of Martius, and of the Anio Vetus, at his own expense, besides erecting fountains in the city. The Aqua Virgo, which received its name from a girl having pointed out to some soldiers the sources of the stream from which it was collected, was brought to Rome by an aqueduct 14,105 paces in length, 12,865 whereof were under ground, and 700 on arches, the remainder being above ground. The Aqua Alsietina, called also Augusta, was 22,172 paces from its source to the city, and 358 paces of it were on arcades. The seven aqueducts above mentioned being found, in the time of Caligula, unequal to the supply of the city, this emperor, in the second year of his reign, began two others, which were finished by Claudius, and opened in the year of the city 803. The first was called Aqua Claudia, and the second Anio Novus, to distinguish it from one heretofore mentioned. The first was 46,406 Roman paces, of which 10,176 were on arcades, and the rest subterranean. The Anio Novus was 58,700 paces in length, 9400 whereof were above ground, 6491 on arches, and the rest subterranean. Some of the arches of these are 100 Roman feet high. All the aqueducts we have mentioned were on different levels, and distributed accordingly to those parts of the city which suited their respective elevations. The following is the order of their heights, the highest being the Anio Novus, 159 feet above level of Tiber: Aqua Claudia, 149 feet; Aqua Julia, 129 feet; Aqua Tepula, Aqua Martia, 125 feet; Anio Vetus, Aqua Virgo, 34 feet; Aqua Appia, 27 feet; and the Aqua Alsietina on the lowest level. The Tiber at Rome being 91·5 feet above the level of the Mediterranean, the mean fall of these aqueducts has been ascertained to be about 0·132 English inches for each Roman pace (58·219 English inches), or 1 in 441. Vitruvius directs a fall of 1 in 200, but Scamozzi says the practice of the Romans was 1 in 500. The quantity of water furnished by six of the aqueducts, as given by Frontinus from a measurement at the head of each aqueduct, is as follows: —

Anio Vetus - - - -	4398 quinariæ.
Aqua Martia - - - -	4690
Aqua Virgo - - - -	2524
Aqua Julia - - - -	1368
Aqua Claudia - - - -	4607
Anio Novus - - - -	4738

The whole supply is given as 14,018 quinariæ, after much fraudulent diversion of the water by individuals; but the diminished quantity is supposed to have been 27,743,100 English cubic feet, or, estimating the population of Rome at one million of inhabitants, 27·74 cubic feet per diem for each inhabitant.

The aqueducts required constant repairs, from the nature of their construction, especially those on arches. The spaces between the piers varied much in width, and necessarily in height. Some of the arcades are as much as 27 feet in diameter.

There are remains of Roman aqueducts in other parts of Europe, even more magnificent than those we have mentioned. One, or the ruins of one, still exists at Metz, and another at Segovia in Spain, with two rows of arcades, one above the other. This last is about 100 feet high, and passes over the greater part of the houses of the city. The most remarkable aqueduct of modern times was that constructed by the order of Louis XIV. for conveying the waters of the Eure to Versailles. It is 4400 feet in length, and contains 242 arcades, each of 50 feet span. The introduction of cast iron pipes has now superseded the erection of these expensive structures.

Arabesque. A building after the Arabian style. See Moresque and Saracenic Architecture, pp. 50, *et seq.* The term is more commonly used to denote that sort of ornament in Moresque architecture consisting of intricate rectilinear and curvilinear compartments and mosaics which adorn the walls, pavements, and ceilings of Arabian and Saracenic buildings. It is capricious, fantastic, and imaginative, consisting of fruits, flowers, and other objects, to the exclusion in pure arabesques of the figures of animals, which the religion forbade. This sort of ornament, however, did not originate with the Arabians; it was understood and practised by the ancients at a very early period. Foliage and griffins, with ornaments not very dissimilar to those of the Arabians, were frequently employed on the friezes of temples, and on many of the ancient Greek vases, on the walls of the baths of Titus at Pompeii, and at many other places. To Raffaele, in more modern times, we are indebted for the most elaborate and beautiful examples of the style, which he even dignified, and left nothing to be desired in it. Since the time of that master it has been practised with varying and inferior degrees of merit, especially by the French in the time of Louis XVI. Arabesques lose their character when applied to large objects, neither should they be employed where gravity in the style is to be preserved.

Arabo-Tedesco. (It. Arabo; and Tedesco, German.) A style consisting of a mixture of Moorish or Low Grecian with German Gothic. It is a term used chiefly by the Italians. An example of this style may be quoted in the baptistery at Pisa (*fig.* 152.), erected by Dioti Salvi in 1152. It is a circular edifice, with an arcade in the second order composed of columns with Corinthian capitals and plain round arches. Between each arch rises a Gothic pinnacle, and above it is finished by sharp pediments enriched with foliage, terminating in a trefoil. See Byzantine and Romanesque Architecture, p. 107, *et seq.*

Aræostyle. (Gr. *αραιος*, wide, and *στυλος*, column.) One of the five proportions used by the ancients for regulating the intercolumniations or intervals between the columns in porticoes and colonnades. Vitruvius does not determine precisely its measure in terms of the diameter of the column. His commentators have tried to supply the deficiency; and, following the progression observable in the intercolumniations he does describe, each of which increases by a semidiameter, the aræostyle would be three diameters and a half. Perrault, in his translation of Vitruvius, proposes that the interval be made equal to four diameters, which is the interval now usually assigned to it. It is only, or rather ought only, to be used with the Tuscan order.

Aræosystyle. (Gr. *αραιος*, wide, *συν*, with, *στυλος*, a column.) A term used by the French architects to denote the method of proportioning the intervals between columns coupled or ranged in pairs, as invented by Perrault, and introduced in the principal façade of the Louvre. It was also adopted by Sir Christopher Wren in the west front of St. Paul's.

Arc. In geometry, a portion of a circle or other curve line. The arc of a circle is the measure of the angle formed by two straight lines drawn from its extremities to the centre of the circle.

Arc-boutant. (Fr.) An arch-formed buttress, much employed in sacred edifices built in the pointed style, as also in other edifices, and commonly called a *flying buttress*, whose object is to counteract the thrust of the main vault of the edifice: it is also called *arched buttress* and *arched butment*. It is no invention of the moderns, as the use of it is found in the baths of Dioclesian.

Arc Doubleau. (Fr.) An arch forming a projection before the sofite of a main arch or vault, in the same manner as a pilaster breaks before the face of a wall.

Arcade. (Fr.) A series of apertures or recesses with arched ceilings or sofites. But the word is often vaguely and indefinitely used. Some so designate a single-arched aperture or enclosure, which is more properly a *vault*; others for the space covered by a continued vault or arch supported on piers or columns; and, besides these, other false meanings are given to it instead of that which we have assigned. Behind the arcade is generally a walk or ambulatory, as in Covent Garden, where the term piazza is ignorantly applied to the walks under the arcade instead of to the whole *place* (*piazza*) or square.

The piers of arcades may be decorated with columns, pilasters, niches, and apertures of different forms. The arches themselves are sometimes turned with rock-worked, and at other times with plain rustic arch stones or voussoirs, or with a moulded archivolt, springing from an impost or platband; and sometimes, though a practice not to be recommended, from columns. The keystones are generally curved in the form of a console, or sculptured with some device. Scamozzi made the size of his piers less, and varied his imposts or archivolts in proportion to the delicacy of the orders he employed; but Vignola made his piers always of the same proportion. See Book III. Chap. I. Sect. 10., and Book III. Chap. I. Sect. 12.

ARCÆ. In ancient Roman architecture, the gutters of the cavedium; arca signifying a beam of wood with a groove or channel in it.

ARCELLA. (Lat.) In mediæval architecture, a cheese room.

ARCH. A mechanical arrangement of blocks of any hard material disposed in the line of some curve, and supporting one another by their mutual pressure. The arch itself is formed of *voussoirs* or arch stones cut in the shape of a truncated wedge, the uppermost whereof is called the *keystone*. The seams or planes, in which two adjacent voussoirs are united, are called the *joints*. The solid extremities on or against which the arch rests are called the *abutments*. The lower or under line of each arch stone is called the *intrados*, and the superior or upper line the *extrados*. The distance between the piers or abutments is the *span* of the arch, and that from the level line of the springing to the intrados its *height*. The subject of arches forms Sect. 9. Book II. Chap. I. of this work, to which the reader is referred for the theory and construction of the arch.

The forms of arches employed in the different styles of English architecture will be found described under the several heads. See p. 172, *et seq.*

ARCHIAS. See ARCHITECTS, list of, 17.

ARCHITECT. (Gr. *αρχος* and *τεκτων*, chief of the works.) A person competent to design and superintend the execution of any building. The knowledge he ought to possess forms the subject of this work; whatever more he may acquire will be for the advantage of his employers; and when we say that the whole of the elements which this work contains should be well known and understood by him, we mean it as a *minimum* of his qualifications. To this we may add, that with the possessions indicated, devotedness, faithfulness, and integrity towards his employer, with kindness and urbanity to those whose lot it is to execute his projects, not however without resolution to check the dishonesty of a builder, should he meet with such, will insure a brilliant and happy career in his profession. We here insert a

Brief Synoptical List of the principal Architects known in History, and their chief Works, from Milizia and other Authorities.

BEFORE CHRIST.

No. in Gloss.	Name of Architect.	Century.	Principal Works.
1	Theodorus of Samos.	7th.	Labyrinth at Lemnos; some buildings at Sparta and the temple of Jupiter at Samos.
2	Hermogenes of Alabanda.	—	Temple of Bacchus at Teos and that of Diana at Magnesia.
3	Agamedes and Trophonius of Delphi.	—	Temple of Apollo at Delphi; a temple dedicated to Neptune near Mantinæa.
4	Demetrius of Ephesus.	6th.	Continuation of the temple of Diana, which had been begun by Chersiphron.
5	Eupalinus of Megara.	—	Aqueduct, with many other edifices, at Samos.
6	Mandrocles of Samos.	—	Wooden bridge over the Thracian Bosphorus, erected by the command of Darius.
7	Chirosophus of Crete.	—	Temple of Ceres and Proserpine, another of the Paphian Venus, and one of Apollo; all at Tegea.
8	Pytheus of Priene.	5th.	Mausoleum of Artemisia in Caria; design for the temple of Pallas at Priene. In the former he was assisted by Statirus.
9	Spentharus of Corinth.	—	Rebuilt the temple of Apollo at Delphi, which had been destroyed by fire.
10	Agaptos of Elis.	—	Portico at Elis.
11	Libon of Elis.	—	Temple of Jupiter Olympius at Olympia.
12	Ictinus of Athens.	—	Parthenon at Athens; temple of Ceres and Proserpine at Elusis; temple of Apollo Epicurius in Arcadia.
13	Callicrates of Athens.	—	Assisted Ictinus in the erection of the Parthenon.
14	Mnesicles of Athens.	—	Propylea of the Parthenon.
15	Antistates of Athens.	—	A temple of Jupiter at Athens.
16	Scopas of Greece.	—	One side of the tomb of Mausolus; a column of the temple at Ephesus.

BEFORE CHRIST.

No. in Gloss.	Name of Architect.	Century.	Principal Works.
17	Archias of Corinth.	5th.	Many temples and other edifices, at Syracuse.
18	Callias of Aradus.	—	Temples, &c., at Rhodes.
19	Ayclius of Aradus.	—	Temple of the Ionian Æsculapius.
20	Mnesthes.	—	Temple of Apollo at Magnesia.
21	Cleomenes of Athens.	4th.	Plan of the city of Alexandria in Egypt.
22	Dinocrates of Macedonia.	—	Rebuilt the temple of Diana at Ephesus; engaged on works at Alexandria; was the author of the proposition to transform Mount Athos into a colossal figure.
23	Andronicus of Athens.	—	Tower of the Winds at Athens.
24	Callimachus of Corinth.	—	Reputed inventor of the Corinthian order.
25	Sostratus of Gnidus.	—	The Pharos of Alexandria.
26	Philo of Athens.	—	Enlarged the arsenal and the Piræus at Athens; erected the great theatre, rebuilt by order of Adrian.
27	Eupolemus of Argos.	—	Several temples and a theatre at Argos.
28	Phæax of Agrigentum.	3d.	Various buildings at Agrigentum.
29	Cossutius of Rome.	2d.	Design for the temple of Jupiter Olympius at Athens.
30	Hermodorus of Salamis.	—	Temple of Jupiter Stator in the Forum at Rome; temple of Mars in the Circus Flaminius.
31	Caius Mutius of Rome.	—	Temple of Honour and Virtue near the trophies of Marius at Rome.
32	Valerius of Ostia.	—	Several amphitheatres with roofs.
33	Batrachus of Laconia.	1st.	These two architects built several temples at Rome. The name of the first (βατραχος), signifies a frog; and that of the latter (σαυρος) a lizard; and they perpetuated their names on some of the works by the allegorical representation of these two animals sculptured upon them. The churches of St. Eusebius and of St. Lorenzo fuori le Murà, at Rome, still contain some columns whose pedestals are sculptured with a lizard and a frog.
34	Saurus of Laconia.	—	
35	Dexiphanes of Cyprus.	—	Rebuilt the Pharos at Alexandria, at the command of Cleopatra, the other having fallen down.
36	Cyrus of Rome.	—	Architect to Cicero.
37	Postumius of Rome.	—	Many works at Rome and Naples.
38	Corceius Auctus of Rome.	—	Grotto of Puzzuoli; grotto of Cumæ, near the lake now called Lago d'Averno.
39	Fussitius of Rome.	—	Several buildings at Rome; the first Roman who wrote on architecture.

AFTER CHRIST.

No. in Gloss.	Name of Architect.	Century.	Principal Works.
40	Vitruvius Pollio of Fano.	1st.	Basilica Justitiæ at Fano. A great writer on architecture.
41	Vitruvius Cerdo of Verona.	—	Triumphal arch at Verona.
42	Celer and	—	Golden house of Nero.
43	Severus of Rome.		

AFTER CHRIST.

No. in Gloss.	Name of Architect.	Century.	Principal Works.
44	Rabirius of Rome.	1st.	Palace of Domitian on Mount Palatine.
45	Mustius of Rome.	—	Temple of Ceres at Rome.
46	Frontinus of Rome.	2d.	He has left a work on aqueducts.
47	Apollodorus of Damascus.	—	Forum Trajani at Rome; a bridge over the Danube in Lower Hungary.
48	Lacer of Rome.	—	A bridge over the Tagus in Spain: a temple now dedicated to San Giuliano.
49	Detrianus of Rome.	—	Moles Hadriani and the Pons Aelius; now called the Castello and Ponte Sant' Angelo.
50	Antoninus, the Senator, of Rome.	—	Pantheon at Epidaurus; baths of Æsculapius.
51	Nicon of Pergamus.	—	Several fine works at Pergamus.
52	Metrodorus of Persia.	4th.	Many buildings in India, and some at Constantinople. The first known Christian architect.
53	Alypius of Antioch.	—	Employed by Julian to lay the foundation of a new temple at Jerusalem.
54	Cyriades of Rome.	5th.	A church and bridge.
55	Sennamar of Arabia.	—	Sedir and Khaovarnack, two celebrated palaces in Arabia.
56	Aloisius of Padua.	—	Assisted in the erection of the celebrated rotunda at Ravenna, the cupola of which is said to have been of one stone, 38 feet in diameter, and 15 feet thick.
57	St. Germain, bishop of Paris, of France.	6th.	Plan of the church of St. Germain at Paris, previously dedicated to St. Vincent; convent at St. Mans.
58	St. Avitus, bishop of Clermont, of France.	—	Church of Madonne du Port.
59	St. Agricola, bishop of Chalons, of France.	—	Cathedral of Chalons, with many other churches in his diocese.
60	Ætherius of Constantinople.	—	Part of the imperial palace, called Chalcis, at Constantinople.
61	Anthemius of Tralles, of Lydia.	—	St. Sophia at Constantinople.
62	Isidorus of Miletus.	—	Assisted Anthemius in the erection of the church of St. Sophia.
63	Chryses of Dara, of Persia.	—	Constructed the celebrated dykes along the Euripus, near Dara, to keep the river in its channel, and to keep out the sea. He was particularly excellent in hydraulic architecture.
64	Isidorus of Byzantium.	7th.	The city of Zenobia in Syria was the work of these two architects.
65	Johannes of Miletus.	—	
66	Saxulphus, abbot of Peterborough, afterwards made bishop of Lichfield, of England.	—	Built the monastery of Medeshampstede, afterwards called Peterborough.
67	Biscopius, Benedict, of England.	8th.	Conventual church of Wearmouth.
68	Egbert, archbishop of York, of England.	—	Rebuilt York Cathedral.
69	Albert, archbishop of York, of England.	—	Completed the building of York Cathedral under Egbert.
70	Eaubald, archbishop of York, of England.	—	Superintended the erection of York Cathedral, under his predecessor, Archbishop Albert.

AFTER CHRIST.			
No. in Gloss.	Name of Architect.	Century.	Principal Works.
71	Romualdus of France.	9th.	The cathedral of Rheims, the earliest example of Gothic architecture.
72	Tietland of Switzerland.	10th.	Convent of Einsidlen in Switzerland.
73	Tioda of Spain.	—	The palace of King Alphonso the Chaste, at Oviedo, now the episcopal palace; churches of St. Salvador, St. Michael, and St. Mary.
74	Ednoth, a monk of Worcester, of England.	—	Superintended the erection of the church and conventual offices of Ramsey Abbey.
75	Dunstan, archbishop of Canterbury, of England.	—	Built for himself a cell at Glastonbury Abbey, and was skilful in mechanics.
76	Ælfric, bishop of Crediton, of England.	—	Built part of Malmsbury Abbey Church, in the reign of Edgar.
77	Elphage, bishop of Winchester, of England.	—	Crypts of Winchester Cathedral.
78	Buschetto of Dulichium.	—	The cathedral or duomo of Pisa, the earliest example of the Lombard ecclesiastical style of architecture. It was built in 1016.
79	Aldhun, bishop of Durham, of England.	—	First cathedral church at Durham.
80	Pietro di Ustamber of Spain.	—	Cathedral of Chartres.
81	Lanfranc, archbishop of Canterbury, of England.	—	Choir of Canterbury Cathedral, burnt in 1174.
82	Remigius, bishop of Lincoln, of England.	11th.	Part of Lincoln Cathedral.
83	Carilepho, bishop of Durham, of England.	—	Began the cathedral church of Durham, on a plan which he had brought with him from France, when he was abbot of St. Vincent's in Normandy.
84	Walkelyn, bishop of Winchester, of England.	—	Said to have erected the oldest part of Winchester Cathedral.
85	Harlewin, abbot of Glastonbury, of England.	—	Rebuilt the abbey church of Glastonbury.
86	Mauritius, bishop of London, of England.	12th.	Built old St. Paul's, in 1083.
87	Gundulf, bishop of Rochester, of England.	—	Rochester Castle; White Tower of the Tower of London; rebuilt Rochester Cathedral.
88	Odo, prior of Croyland, of England.	—	Monastic church of Croyland. Arnold, a lay brother of the abbey, was employed under Odo as mason.
89	Ernulf, bishop of Rochester, of England.	—	Completed Gundulf's works at Rochester.
90	Alexander, bishop of Lincoln, of England.	—	Rebuilt Lincoln Cathedral.
91	Ranulf, or Ralf Flambard, bishop of Durham, of England.	—	Part of Durham Cathedral; Norham Castle.

AFTER CHRIST.

No. in Gloss.	Name of Architect.	Century.	Principal Works.
92	Henry of Blois, bishop of Winchester, of England.	12th.	A most celebrated architect; built the conventual churches of St. Cross and Rumsey in Hampshire.
93	Raimond of Montfort, of France.	—	Cathedral of Lugo.
94	Dioti Salvi of Italy.	—	Baptistery of Pisa, near the Campo Santo. His works were in the Lombard style, and were overloaded with minute ornaments.
95	Buono of Venice.	—	The tower of St. Mark at Venice, which is 330 feet high, and 40 feet square, built in 1154; a design for enlarging the church of Santa Maria Maggiore at Florence, of which the master walls still exist; the Vicaria and the Castello del' Uovo at Naples; church of St. Andrew at Pistola; la Casa della Città; campanile at Arezzo.
96	Sugger of St. Denis, of France.	—	Rebuilt the church and abbey of St. Denis, near Paris. He was distinguished by his perfection in the Gothic style.
97	Roger, archbishop of York, of England.	—	None of his works at this cathedral are now remaining.
98	Pietro di Cozzo da Limena of Italy.	—	The celebrated great hall at Padua, which is 256 feet long, 86 wide, and 72 high, built in 1172, burnt in 1420, and restored by two Venetian architects, Rizzo and Piccino; it was dismantled by a whirlwind in 1756, and again restored by Ferracina.
99	Wilhelm, or Guglielmo, of Germany.	—	The hanging tower at Pisa, built in 1174. Bonnano and Tomaso, two sculptors of Pisa, were also engaged upon it.
100	William of Sens, of England.		Canterbury Cathedral.
101	Sisseverne, monk of St. Alban's, of England.	—	St. Alban's Abbey Church.
102	Goldclif, Hugo de, of England.	—	St. Alban's Abbey.
103	Eversolt, Gilbert de, of England.	—	St. Alban's Abbey.
104	Baldwin, archbishop of Canterbury, of England.	—	Church at Hackinton, near Canterbury; and another at Lambeth.
105	Isembert of Xaintes, of France.	13th.	Bridges of Xaintes and Rochelle. Recommended by King John to the citizens of London as a proper person to finish London Bridge, begun by Peter of Colechurch.
106	Peter of Colechurch, of England.	—	Began London Bridge.
107	Bertram, canon of Salisbury, of England.	—	Overseer of the works of Salisbury Cathedral, under John and Henry III. Lord Orford supposes he was the same person who is called Elyas the Engineer, in a record of the reign of King John, relating to the repair of the king's houses at Westminster in 1209.
108	Fitz-Odo, Edward, of England.	—	Master of the works at Westminster under Henry III.
109	Eustachius, bishop of Ely, of England.		Gallery of Ely Cathedral.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
110	Robert of Lusarches, of France.	13th.	Cathedral of Amiens, which was continued by Thomas de Cormont, and finished by his son Renauld.
111	Etienne de Bonneveil of France.	—	Church of the Trinity at Upsal, in Sweden, built after the model of that of Notre Dame at Paris.
112	Poore, bishop of Salisbury, of England.	—	Began Salisbury Cathedral.
113	Melsonby, bishop of Salisbury, of England.	—	Part of the cathedral of Durham.
114	Hoo, W. de, prior of Rochester, of England.	—	Choir of Rochester Cathedral.
115	Jean d'Echelles of France.	—	The portico of the cathedral of Notre Dame at Paris.
116	Pierre de Montereau of France.	—	The holy chapel at Vincennes; the refectory, dormitory, chapter-house, and chapel of Notre Dame, in the convent of St. Germain des Prez, near Paris.
117	Eudo de Montreuil of France.	—	Church of the Hotel Dieu at Paris; churches of St. Catherine du Val des Ecoliers, of St. Croix de la Bretonnerie, of Blancs Manteaux, of the Mathurins, of the Cordeliers, and of the Carthusians, at Paris. His style was unpleasing and heavy.
118	San Gonsalvo of Portugal.	—	Stone bridge at Tui.
119	San Pietro of Portugal.	—	Stone bridge called Il Ponte de Carez.
120	Lapo, or Jacopo, of Germany.	—	Convent and church of St. Francisco at Assisi; Palazzo del Barjello; and the façade of the archbishop's palace at Florence.
121	Nicola da Pisa, of Pisa.	—	Convent and church of the Dominicans at Bologna; church of San Micheli; some palaces; and the octagonal campanile of the Augustins at Pisa; the great church del Santo at Padua; church of Santa Maria at Orvietto; church de'i Fratri Minori at Venice; abbey and church in the plains of Taliacozzo, in the kingdom of Naples, built as a memorial of the victory obtained there by Charles I. over Conrad; plans of the church of San Giovanni at Sienna; of the church and convent della Santissima Trinita at Florence, and of those of the Dominicans at Arezzo, which were built by Maglione, his scholar; the repairs and alterations to the duomo at Volterra; the church and convent of the Dominicans at Viterbo. He intermixed the Gothic with the Lombard style.
122	Fuccio of Italy.	—	Church of Santa Maria sul Arno at Florence; the gates against the river Volturno at Capua; he finished the Vicaria and Castello dell' Uovo at Naples, which were commenced by Buono; he was distinguished for his skill in fortification.
123	Fenante Maglione, disciple of Nicola of Pisa.	—	Cathedral and church of San Lorenzo at Naples; the Palazzo Vecchio at Naples, in conjunction with Giovanni Benin Casa; the church and convent of the Dominicans at Arezzo.

AFTER CHRIST.

No. in Gloss.	Name of Architect.	Century.	Principal Works.
124	Masuccio of Naples.	13th.	Church of Santa Maria della Nuovo at Naples; churches of S. Dominico Maggiore and S. Giovanni Maggiore; the archiepiscopal palace and Palazzo Colombrano at Naples.
125	Arnolfo Fiorentino of Florence.	14th.	The church of Santa Croce at Florence; the walls of the city, with the towers; Palazzo della Signoria, now called Il Palazzo Vecchio; model and plan of the cathedral of S. Maria del Fiore, to which the cupola was added by Brunelleschi; the abbey and Piazza San Micheli; Piazza dei Priori. His works were greatly admired.
126	Pietro Perez of Spain.	—	The cathedral of Toledo.
127	Robert de Courcy of France.	—	Rebuilt the cathedral at Rheims.
128	Erwin von Steinbach of Germany.	—	Celebrated minster at Strasburg was superintended by him for twenty-eight years.
129	Giovanni da Pisa of Pisa.	—	Campo Santo, or public cemetery, at Pisa; the tribune of the Duomo in the same city; Castel Nuovo and the church of Santa Maria della Nuovo at Naples; façade of the cathedral at Sienna: many churches and palaces at Arezzo and other towns in Italy. He was the first architect in the modern style of fortification, and his churches and other buildings possess great merit. He was the son and scholar of Nicola da Pisa.
130	Andrea da Pisa of Pisa.	—	Plan of the fortress della Scarperia at Mugello, at the foot of the Apennines; plan and model of the church of San Giovanni at Pistoja; the ducal Palazzo Gualtieri at Florence. He was distinguished as a military architect.
131	Agostino da Sienna, or da Pisa, of Italy. Angelo, his brother, of Italy.	—	The north and west façades of the cathedral of Sienna, as also the two gates; the church and convent of St. Francis; Palazzo de' Nove Magistrati; grand fountain in the piazza opposite the Palazzo della Signoria; hall of the council chamber, and Palazzo Publico; the church della Santa Maria in Piazza Manetti wer built by him in conjunction with Angelo da Pisa, who was his brother.
132	Boyden, William, of England.	—	Chief architect to the chapel of the Virgin at St. Alban's Abbey Church, erected during the abbacy of Hugo de Eversden.
133	Bek, A. de, bishop of Durham, of England.	—	Built and enlarged Barnard Castle, and other fortresses.
134	Henry Latomus, or the stonecutter, abbot of Evesham, of England.	—	Chapter-house, dormitory, refectory, abbot's hall, and kitchen of the monastery at Evesham.
135	Helpstone, J., of England.	—	New-tower or water-tower, in the walls of Chester.
136	Eversden, Hugh de, abbot of St. Alban's, of England.	—	Lady chapel in St. Alban's Abbey Church.
137	Walter Weston of England.	—	St. Stephen's Chapel, Westminster.
138	Thomas of Canterbury, of England.	—	St. Stephen's Chapel, Westminster.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
139	Giacomo Lanfrani of Italy.	14th.	Church of St. Francis at Imola; church of St. Antonio at Venice.
140	Juan Rari of France.	—	Finished the building of the church of Notre Dame at Paris.
141	William of Wykeham, bishop of Winchester, of England.	—	New College, Oxford; part of Winchester Cathedral; plan of Windsor Castle.
142	Walsingham, prior of Ely, of England.	—	Lantern tower and tower of Ely Cathedral.
143	Rede, bishop of Chichester, of England.	—	An eminent mathematician; built first library at Merton College, Oxford; Amberly Castle, Sussex.
144	Andrea di Cione Orgagna, of Florence.	—	Additions to the ducal palace at Florence; his brother built the tower and gate of San Pietro Gattolini.
145	Gainsborough, or Gaynisburg, of England.	—	An architect employed at Lincoln Cathedral. On his monument, still existing in the cathedral, he is said to have died in June, M.C.CC—, the last portion of the date being obliterated.
146	Chichele, archbishop of Canterbury, of England.	15th.	Founded All Souls College; built a monument for himself in Canterbury Cathedral; made additions to Canterbury Cathedral, Lambeth Palace, Croydon Church, and Rochester Bridge.
147	Filippo Brunelleschi of Florence.	—	Cupola of the cathedral of Santa Maria del Fiore at Florence. A council of artists was held at Florence in 1420, to consider and advise on this scheme, at which even English artists are said to have assisted; after a diversity of opinions, Brunelleschi's project was approved of and adopted. His other principal works were, the Palazzo Pitti, which was begun and half finished by him, the remainder being the work of Luca Fancelli; a great part of the church of San Spirito; the church degl' Angeli, designed and begun, but not completed, from want of money; the monastery de' Camaldosi; the fortress of Milan, and several works about that city; a model for the fortress of Pesaro; the old and new citadel at Pisa; some other works there, as well as at Trento, and in other parts of Italy. He drained the country round Mantua, and set the first example of a purer style in the architecture of Italy.
148	Michelozzo Michelozzi of Florence.	—	Palazzo di Medici, now dei Marchesi Ricardi; Palazzo Caffajiulo; convent of the Dominicans; Noviziato della Santa Croce; chapel in the church dei Servi; Palazzo della Villa Careggi; Palazzo Tornabuoni, now dei Marchesi Corsi; and several other palaces, churches, and convents at Florence; monastery of the Black Benedictines at Venice, and the Palazzo della Villa Careggi at Mujello; some buildings at Trento; a beautiful fountain at Assisi, la Citadella Vecchia at Perugia; the alterations to the palace presented by Francisco Sforza to Cosmo di Medici, whom he followed in his exile, and other great works in various parts of Italy.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
149	Giuliano of Majano, near Florence.	5th.	Palazzo del Poggio Reale at Naples; a Corinthian triumphal gate at the Castel Nuovo; many fountains in the same city; the Cortile S. Damaso, in the Vatican at Rome, whither he was invited by Paul II.; palace and church of San Marco at Rome; he also enlarged the church at Loreto.
150	Frowcester, Walter, abbot of Gloucester, of England.	—	Built the great cloisters of his monastery in 1400.
151	Keyes, Roger, of England.	—	Architect of All Souls' College, Oxford.
152	Horwood, W., a freemason, of England.	—	Collegiate chapel of Fotheringhay.
153	Close, or Cloos, bishop of Lichfield, of England.	—	Supposed to have designed King's College chapel, Cambridge; though, according to Hearne, his father was the architect.
154	Christobolo of Italy.	—	A mosque at Constantinople, with eight schools and eight hospitals, on the site of the church of the Apostles, by order of Mahomet II.
155	Baccio Pintelli of Florence.	—	Church and convent of Santa Maria del Popolo at Rome; the celebrated Capella Sistina in the Vatican; the hospital of S. Spirito in Sassia; Ponte Sisto; designs for the church of San Pietro in Montorio; the church of S. Sisto; the church of St. Agostino and the church of San Pietro in Vincolà at Rome; rebuilt the church and convent of St. Francis at Assisi; and built the palace for the Cardinal del Rovere at Borgo Vecchio; some attribute to him the palace built for the Duke Federigo Feltre at Urbino. He is said to have been the first to set the example of grandeur in the architecture of chapels.
156	Bartolomeo Bramantino of Italy.	—	Church of San Satiro at Milan, and other works in various parts of Italy.
157	Giovanni del Pozzo of Spain.	—	Dominican convent, and a great bridge over the Huexar, near Cuença.
158	Andrea Ciccione of Naples.	—	Convent and church of Monte Oliveto; palace of Bartolomeo da Capua; and several other convents and palaces in the city of Naples.
159	Ridolfo Fioravanti of Bologna.	—	Restored the hanging tower of the church of S. Biagio, at Cento, to its perpendicular position, and built many churches at Moscow.
160	Orcheyarde, W., of England.	—	Architect of Magdalen College, Oxford, under Bishop Wayneflete.
161	Francesco di Giorgio of Sienna.	—	The ducal palace at Urbino.
162	Leon Battista Alberti of Florence.	—	Church of St. Francis at Rimini; church of St. Andrew at Mantua; the principal façade of Santa Maria Novella, at Florence, has been attributed by some to Alberti; but from the circumstance of its being Gothic, it may with much more probability be assigned to Bettini; the gate and Corinthian loggie are, however, from the designs of Alberti, as also the Doric façade of the Palazzo Rucellai, and the choir and tribune of the church della Nunziata, all at Florence. He also repaired

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
			the Aqua Vergine and the fountain of Trevi, at Rome, under Nicholas V.; the palace for the Duke Federigo Feltre at Urbino; and many other buildings in Italy.
163	Farleigh, or Ferley, W., abbot of Gloucester, of England.	15th.	Built the lady chapel of Gloucester, about 1490.
164	Beauchamp, bishop of Sarum, of England.	—	Appointed surveyor of the works at Windsor Castle by Edward IV.; supposed to have made designs for rebuilding St George's Chapel; built a chantry chapel in Salisbury Cathedral.
165	Wayneflete, bishop of Winchester, of England.	—	Founder of Magdalen College, Oxford; overseer of the building at Windsor. Leland was informed that the greatest part of the buildings of Eton College were raised under his direction, and at his expense.
166	Kendale, John, of England.	—	Supervisor of all the king's works.
166*	Druell, J., archdeacon of Exeter, of England.	—	One of the architects employed on All Souls' College, Oxford.
167	Bramante Lazzari, or Bramante d'Urbino, of Castel Durante, near Urbino.	—	First designed and commenced the building of St. Peter's at Rome; a small model was executed after the same design for an insulated church without the walls of Todi; many works in the Vatican, particularly the library and the Belvedere court, with a magnificent design for alterations to be made in it, under Julius II.; the rotondo in the convent of San Pietro Montorio; the palaces of S. Giacomo Scosciacavalli ora de' Conti Giraud, del Duca de Sora, della Cancellaria, dell Nuovo dell' Imperiale; the churches of SS. Euloy de' Orfani, Lorenzo and Damaso; the cloisters of the monastery della Pace, &c. at Rome; the Strada Julia in that city; the ducal palace at Urbino; Palazzo Publico at Brescia; design for the church dell' Umiltà at Pistoja.
168	Ventura Vitoni of Pistoja.	—	Church dell' Umiltà at Pistoja, after the design of Bramante, whose pupil he was.
169	Alcock, J., bishop of Ely, of England.	16th.	Sepulchral chapel in Ely Cathedral; episcopal palace at Downham; supposed to have designed St. Mary's, or the University Church, Cambridge.
170	Moston, J., of Cambridge, of England.	—	Part of palace of Lambeth; another at Canterbury; "made a great building at Charing in Kent;" almost the whole house of Forde. He built at Alington Park.
171	Gabriello d'Agnolo of Naples.	—	Church of S. Giuseppe; church of Santa Maria Egiziaca; palace of Ferdinando Orsini, duke of Gravina, at Naples.
172	Gian Francesco Normando of Florence.	—	Church of S. Severino; Palazzo Filomarini; Palazzo Cantalupo at Naples; several buildings in Spain.
173	Pietro Lombardo of Venice.	—	Tomb of Dante, the poet, in the church of St. Francis at Ravenna; church of SS. Paolo, and Giovanni, and monastery adjoining the church of Santa Maria Mater Domini; clock-tower in the square of St. Mark; German warehouse on the Rialto; school della Misericordia; cloister of Santa Giustina at Padua.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
174	Martino Lombardo of Venice.	16th.	School or confraternità of San Marco, and, perhaps, the church of S. Zaccaria at Venice.
175	John Cole of England.	—	Builder of Louth Spire, Lincolnshire.
176	Sir Reginald Bray of England.	—	Design of Henry VII.'s Chapel, Westminster, and of other works at St. George's Chapel, Windsor.
177	John Hylmer of England.	—	St. George's Chapel, Windsor.
178	Giuliano di San Gallo of Florence.	—	Cloister of the Carmelites di Santa Maddelena de' Pazzi at Florence; cloister for the Fratri Eremitani di S. Agostino; la Gran Fabbrica del Poggio Imperiale, fortress near the Porto a Prato, and other works, at Florence; a magnificent palace at Poggio Cajana for Lorenzo di Medici; repaired the cupola of the church della Madonna at Loreto; restored the roof and decorations of the ceiling of the church of Santa Maria Maggiore; restored the church dell' Anima; Palazzo Rovere, near San Pietro in Vincolà at Rome; Palazzo Rovere at Savona; an unfinished palace at Milan; fortress and gate of San Marco, of the Doric order; many palaces at Pisa; fortifications at Ostia.
179	Simone Cronaca, or Pollajolo, of Florence.	—	Façade of the Palazzo Strozzi at Florence; church of S. Francis at S. Miniato, near Florence; convent of the Padri Serviti; sacristy of Santo Spirito, and the council chamber at Florence.
180	Aristotle Abberti of Bologna.	—	A bridge in Hungary; several churches in Russia.
181	Leonardo da Vinci, near Florence.	—	Aqueduct of the Adda at Milan; various machines, plans, and works on architecture.
182	Fra Giocondo of Verona.	—	Many bridges, especially that of Notre Dame at Paris; the public hall and Ponte della Pietra at Verona; fortifications at Treviso; cleansing of the Lagunes, and a design for the Ponte Rialto at Venice: after the death of Bramante, he was engaged with Rafaelle and San Gallo in erecting St. Peter's at Rome.
183	Novella da San Lucano of Naples.	—	Palace of Prince Robert Sanseverino, duke of Salerno, at Naples; and the restoration of the church of San Domenico Maggiore, which was built by Lucano.
184	Percy, John, abbot of Leicester, of England.	—	Brick buildings at Leicester Abbey.
185	Rafaelle d'Urbino of Urbino.	—	Continued the erection of St. Peter's at Rome, after the death of Bramante, his master in architecture; engaged on the buildings of the Farnese Palace; church of Santa Maria in Navicella, repaired and altered; stables of Agostino, near the Palazzo Farnese; Palazzo Caffarelli, now Stoppani; the gardens of the Vatican; the façade of the church of San Lorenzo, and of the Palazzo Uggoccioni, now Pandolfini, at Florence.
186	Bolton, W., prior of St. Bartholomew's of England.	—	Supposed to have designed Henry VII.'s Chapel, where he was master of the works.

AFTER CHRIST.			
No. in Gloss.	Name of Architect.	Century.	Principal Works.
187	John of Padua of Italy.	16th	"Deviser of buildings" to Henry VIII. of England.
188	Gibbes, W., last prior of Bath, of England.	—	Continued the building of Bath Abbey church till the dissolution of monasteries.
189	Hector Asheley of England.	—	Surveyor of buildings, employed in the erection of Hunsdon House.
190	Andrea Contucci di Monte Sansovino of Italy.	—	The beautiful chapel del Sagramento in the church di Santo Spirito; palace della Canonica at Loreto; a cloister for the monks of St. Agostino, and a little chapel without the walls of Sanseverino; some buildings at Venice, and many in Portugal.
191	Bartolomeo Buono of Bergamo, of Italy.	—	Church of S. Rocco; some parts of the Campanile di San Marco, and the Procurazie Vecchie at Venice.
192	Guglielmo Bergamasco of Bergamo, of Italy.	—	Capella Emiliana of the Camaldulenses at Murano, an island of the Lagunes; Palazzo di Calmerlinghi, near the Ponte Rialto at Venice; palace at Portagruaro, at Friuli; gate di Santo Tommaso at Treviso; gate called Il Portello at Padua.
193	Maestro Filippo of Spain.	—	Restoration of the cathedral of Seville.
194	Giovanni di Ololzago of Biscay, of Spain.	—	Cathedral of Huesca in Arragon: he blended the modern Greek style with the Gothic, in the manner called Arabo-tedescho.
195	Pietro di Gamiel of Spain.	—	Convent of S. Eugraçia at Saragossa; college of Alcala, in the Græco-Gothic style of architecture.
196	Giovanni Alonzo of Spain.	—	Sanctuary of Guadaloupe.
197	Fra Giovanni d'Escobedo of Spain.	—	Grand aqueduct of Segovia, by order of Queen Isabella.
198	Giovanni Campero of Spain.	—	Church and convent of S. Francis at Fordelaguna.
199	Antonio San Gallo of Mugello, near Florence.	—	Churches of the Madonna di Loreto near Trajan's column, of Santa Maria di Monserrato, of S. Giovanni dei Fiorentini; Palazzetto di Conte Palma; Palazzi di Santo Buono for himself, now that of the Marchesi Sacchetti; Farnese, begun by Paul III., when a cardinal; fortifications of Civita Vecchia, of Civita Castellana, of Parma, Ancona, and many other strong places in Italy; he altered the Mole of Adrian to its present form of the castle of S. Angelo; triumphal arch in the square of S. Mark at Venice; a temple to our Lady at Monte Pulciano; built the Capella Paolina del Vaticano, and assisted in the works of St. Peter's.
200	Baldassare Peruzzi of Volterra.	—	Plan and model of the cathedral or duomo at Carpi; two designs for the façade of San Petronio, and the gate of San Michele in Bosco at Bologna; fortifications at Sienna; the little palace built for Agostino Chigi, now called the Farnesina, in the Lungara; Palazzo Massimi, near the church of San Pantaleo; Villa di Papa Giulio III.; the cortile of the palace de' Duchi Altemps; casino at the Palazzo Chigi; tomb of Pope Hadrian IV. in

AFTER CHRIST.			
No. in Gloss.	Name of Architect.	Century.	Principal Works.
			the church dell' Anima; Palazzo Spinosa, now the hospital degli Eretici convertiti at Rome; assisted in the erection of St. Peter's, and was buried by the side of Rafaelle, in the Pantheon. His style was good.
201	Marco di Pino of Sienna.	16th	Modernised the church della Trinità di Palazzo, and built the church and convent of Giesù Vecchio at Naples.
202	Andrea Briosco of Padua.	—	The Loggia and council house in the Piazza degli Signori at Padua, finished in 1526.
203	Ferdinando Manlio of Naples.	—	Church and hospital della Nunziata; the Strada di Porta Nolano, and di Monte Oliveto, with other streets and palaces at Naples; a bridge at Capua.
204	Giovanni Merliano of Nola of Italy.	—	Strada di Toledo at Naples; church of S. Giorgio de' Genovesi; church of S. Giacomo degli Spagnuoli; plan of the palace del Principe di San Severo, and the palace of the Duca della Torre; the Castel Capuano, altered to a court of law; a fountain at the extremity of the Mole, and some triumphal arches for the entrance of Charles V., on his return from Tunis, at Naples.
205	Giovanni Gil de Hontanon of Spain.	—	Plan of the cathedral of Salamanca.
206	Baccio d'Agnolo of Florence.	—	The beautiful bell tower or campanile of Santo Spirito; lantern above the cupola of Santa Maria del Fiore, great altar and choir of which was built by his son Giuliano; palace for Giovanni Bartolini in the Piazza della Santissima Trinità; Palazzo Salvieto at Rome.
207	Giovanni Maria Falconetto of Verona.	—	Church della Madonna delle Grazie, for the Dominicans at Padua; palace in the Castel d'Usopo in the Friuli; palace for Luigi Cornaro, near the Santo; Doric gate to the Palazzo Capitano; a music hall, which was much admired by Serlio, who denominated it "La Rotondo di Padoua;" gates of SS. Giovanni and Savonarola.
208	Rodrigo Gil de Hontanon of Spain.	—	Superintended the erection of the cathedral of Salamanca; built the cathedral of Segovia.
209	Pietro de Uria of Spain.	—	Bridge of Almaraz, over the Tagus.
210	Alonzo de Cobarrubias of Spain.	—	Façade of the Alcazar at Toledo; convent and church of S. Michael at Valenza; repaired the church of Toledo, which was erected in 587, during the reign of King Riccaredo.
211	Diego Siloe of Toledo.	—	Cathedral and Alcazar at Granada; church and convent of S. Jerome in the same city.
212	Girolamo Genga of Urbino.	—	Palace of the Duke of Urbino, sul Monte dell' Imperiale; the court of the palace restored; church of San Giovanni Battista at Pesaro; façade of the cathedral and the bishop's palace at Mantua; convent de' Zoccolanti at Monte Baroccio. His son, Bartolomeo, was also an artist of considerable repute, and there are several of his works at Mondavio, Pesaro, and other parts of Italy.
213	Michele San Micheli.	—	Cathedral of Monte Fiascone; church of S. Domenico at Orvieto; numerous fortresses in

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
			the Venetian territory, in Corfu, Lombardy, and the ecclesiastical states, as at Legnani, Orzi Nuovo, and Castello; palaces di Canossa, dell' Gran Guardia on the Bra; Pellegrini de' Versi; the prefecturate and façade of the Palazzo Bevilaqua at Verona; chapel Guareschi in the church of S. Bernardino; design for the campanile of the Duomo; churches of Santa Maria in Organo de' Monaci, di Monte Oliveto, di San Giorgio, and della Madonna della Campagna, in the same city; gates Nuova, del Pallio, di S. Zenone, del Palazzo Pretorio, and del Palazzo Prefettizio, at Verona; fortifications of the same city, the first instance of the introduction of triangular bastions; the first bastion, that of della Madellina, was erected in 1527.
214	Philibert de Lorme of France.	16th.	Commenced the Tuilleries; built the châteaux of St. Maur, Anet, Meudon, and many others.
215	Galeazzo Alessi of Italy.	—	The Escurial in Spain; he was much employed at Genoa.
216	Sante Lombardo of Venice.	—	Palazzo Vendramini; staircase and façade of the school of S. Rocca; palaces Trevisani and Gradenigo, at Venice.
217	Giacomo Barozzi da Vignola of Rome.	—	The magnificent palace at Caprarola for Cardinal Farnese.
218	Giulio Pippi, or Giulio Romano, of Rome.	—	Villa Madama; Palazzo Lante at San Pietro; church della Madonna del Orto; Palazzo Ciccia porci alla Strada di Banchi; Palazzo Cenci sulla Piazza S. Eustachio, near the Palazzo Lante, and other buildings in Rome; Palazzo del T. at Mantua; palace at Marmiruolo, five miles from Mantua; modernising and enlarging the ducal palaces, the Duomo, and many other buildings in the same city; façade of S. Petronio at Bologna; and some works at Vicenza. His style was agreeable.
219	Michel Angelo di Buonaroti of Florence.	—	Library of the Medici, generally called the Laurentian Library, at Florence; model for the façade of the church of San Lorenzo; second sacristy of Lorenzo, commonly called the Capella dei Depositi; church San Giovanni, which he did not finish; fortifications at Florence, and at Monte San Miniato; monument of Julius II. in the church of San Pietro in Vincolà at Rome; plan of the Campidoglio; palace of the Conservatori; building in the centre, and the flight of steps in the Campidoglio, or Capitol, at Rome; continuation of the Palace Farnese, and several gates at Rome, particularly the Porta Nomentana or Pia; steeple of S. Michaele at Ostia; Carthusian church of Santa Maria degli Angeli; the gate to the vineyard del Patriarca Grimani; tower of S. Lorenzo at Ardea; church of Santa Maria, in the Certosa, at Rome; many plans of palaces, churches, and chapels. He was employed on St. Peter's, after the death of San Gallo.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
220	Mascall or Marshall, Eustace, of England.	16th.	Clerk of the works to Cardinal Wolsey, at the building of Christchurch College, Oxford; and chief clerk of accounts for all the buildings of Henry VIII. within twenty miles of London.
221	Damiano Forment, of Valenza of Spain.	—	Façade of the church of S. Eugraçia, at Saragossa.
222	Martino de Gainza of Spain.	—	The chapel royal at Seville.
223	Alonzo Berruguette, of Parades, de Naba, of Spain.	—	Plan of the former royal palace at Madrid; gate of S. Martino at Toledo; palace of Alcala in that city; he also assisted at the erection of the cathedral of Cuença.
224	Pietro di Valdevira of Spain.	—	The beautiful chapel of S. Salvador, at Ubeda; palace in the same place; hospital and chapel of S. Jago at Baeza.
225	Pietro Ezguerra of Ojebar, of Spain.	—	Cathedral of Plasentia; church of S. Matteo de Caceres; church of Malpartida.
226	Ferdinando Riuz of Cordova, of Spain.	—	Heightened the great steeple of the cathedral of Seville, called the Torre della Giralda.
227	Machuca of Spain.	—	Royal palace of Grenada.
228	Antonio Fiorentino of Florence.	—	Church of Santa Catarina a Formello at Naples; the cupola of this church is said to have been the first that was raised of any considerable magnitude in that city.
229	Jacopo Tatti, surnamed Sansovino, of Florence.	—	Church of S. Marcello begun, and that of S. Giovanni de Fiorentini built; Loggia, on the Via Flaminia, just out of the Porto del Popolo, for Marco Coscia; Palazzo Gaddi, now del Nicolini, at Rome; church of St. Francesco della Vigna, which was finished by Palladio; Palazzo Cornari, sul Canal Grande, at San Maurizio; mint and other public buildings at Venice; church of San Fantino; church of San Geminiano, &c. His style was of the Venetian school.
230	Theodore Havens of England.	—	Caius College, Cambridge, a good specimen of the architecture of the day.
231	Domenico Teocopoli of Greece.	—	College of the Donna Maria d'Arragona at Madrid; church and convent of the Dominican nuns; also of the Ayuntamiento at Toledo; church and convent of the Bernardine nuns at Silos.
232	Garzia d'Emere of Spain.	—	Parochial church of Valeria, near Cuença.
233	Bartolomeo di Bustamente of Spain.	—	Hospital of St. John the Baptist, near Toledo.
234	Giovan Battista di Toledo of Spain.	—	Designs for the Escurial; he assisted in planning the street of Toledo at Naples, the church of S. Jago, belonging to the Spaniards; palace at Posilipo in the same city.
235	John Thynne of England.	—	Built Somerset House in 1567.
236	Giovanni d'Herrera, of Movellar, of Austria.	—	Continued the Escurial after the death of his master, Giovan Battista; plan of the church of S. Jago, near Cuença; bridge of Segovia at Madrid; palace of Aranjuez.
237	Pierre de Lescot of France.	—	Fontaine des Innocens, in the Rue Saint Denys, at Paris.
238	Sebastiano Serlio of Bologna.	—	Palace of Grimani at Venice; employed by Francis I. of France at Fontainebleau.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
239	Bartolomeo Ammanati of Italy.	16th.	Palazzo Pitti; bridge Santissima Trinità; Rucellai Palace at Florence; Jesuit's college at Rome, and many other works.
240	Nicholas Abate of Modena.	—	The old château of Meudon, tomb of Francis I. at St. Denys; decorated the apartments of the palace of Fontainebleau.
241	Andrea Palladio of Vicenza, of Italy.	—	Olympic Theatre at Vicenza; Il Redentore at Venice; and, perhaps, more public and private buildings than have been erected before or since by any architect.
241*	Bernardo Buontalenti of Florence.	—	Villa of Marignolle, now Casa Capponi; the casino behind San Marco at Florence; a palace for the Acciajuoli, now the Corvini; the façade of the Strozzi Palace in the Via Maggiore; the façade of the church della Santissima Trinità; and works in many other parts of Italy.
242	Domenico Fontana of Milan.	—	Chapel of the Manger in the church of S. Maria Maggiore; library of the Vatican, and many other works.
243	John Shute of England.	—	A painter and architect, who flourished during the reign of Queen Elizabeth, from 1558 to 1608.
244	Robert Adams of England.	—	Superintendent of royal buildings to Queen Elizabeth.
245	Louis de Foix of France.	—	Monastery of the Escurial in Spain; the new canal of the Adour; "Tour de Cordouan," at the mouth of the Garonne.
246	Jaques Androuet du Cerceau of France.	—	Pont Neuf at Paris; hotels de Sully, de Mayenne, and that of the Fermes Général; designed the fine gallery built by Henri IV. at the Tuilleries.
247	Vincenzo Scamozzi of Vicenza.	—	Supposed inventor of the angular Ionic capital; made some additions to the library of S. Mark, finished the Olympic Theatre at Vicenza, and built a theatre at Sabionetta.
248	Jacques de Brosse of Paris.	—	Luxembourg at Paris, and other works.
249	Carlo Maderno of Lombardy.	—	Altered Michel Angelo's design for St. Peter's at Rome, from a Greek to a Latin cross; began the palace of Urban VIII.
250	John Warren of England.	17th	Architect of St. Mary's Church tower, Cambridge.
251	Sir H. Wotton of England.	—	Author of "The Elements of Architecture," published in London, 1624.
252	Inigo Jones of England.	—	Banqueting House; chapel, Lincoln's Inn; Surgeons' Hall; arcade, Covent Garden, London; and a vast number of other important works.
253	Giovanni Battista Aleotti of Ferrara.	—	Fortress at Ferrara; many palaces, theatres, and other public buildings at Mantua, Parma, Modena, and Venice.
254	Pierre le Muet of France.	—	Plan for the grand hotel of Luynes; hotel Laigle and Beauvilliers.
255	Francesco Borromini of Italy.	—	Author of "numerous absurdities" at Rome and Florence, nevertheless much employed.
256	Alessandro Algardi of Bologna.	—	Chiefly employed at Rome.
257	Giovanni Lorenzo Bernini of Naples.	—	The celebrated piazza, colonnade, and staircase at St. Peter's; grand fountain of the Piazza Navona.
258	François Mansard of France.	—	Abbey of Val de Grace; Château des Masons; portal of the Minims in the Place Royale.

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
259	Claude Perrault of France.	17th.	Façade of the Louvre; chapel of Sceaux; chapel of Notre Dame in the church of the Petits Pêres.
260	François Blondel of France.	—	Bridge over the Charente at Saintes; gate of S. Denis at Paris; repair and decorations of the gates of S. Antoine and S. Bernard.
261	Antoine le Pautre of France.	—	Wings of St. Cloud; church of the nunnery of Port Royal; hotels of Gevres and Beauvais.
262	Jaques le Mercier of France.	—	Sorbonne, Palais Royal, S. Roch, Val de Grace, were erected by him after the designs of Mansard.
263	Christmas Gerard of England.	—	Designed Aldersgate, London; was an architect and sculptor.
264	Sir Christopher Wren of England.	—	St. Paul's; city of London after the Fire; Hampton Court; Greenwich Hospital, &c.
265	Robert Hooke of England.	—	The Old Bethlem Hospital in Moorfields; Ashe's Alms-houses; British Museum. He was associated with Wren. He gave a plan for rebuilding London after the Fire.
266	Carlo Fontana of Italy.	—	One of the last architects of St. Peter's.
267	Jules Hardouin Mansard of France.	—	Dòme des Invalides; Gallerie du Palais Royal; the Place de Louis le Grand; that des Victoires, &c. He was the nephew of Francis Mansard.
268	Rev. H. Aldrich of England.	—	Three sides of the quadrangle of Christ's Church, called Peckwater Square, chapel of Trinity College, and church of All Saint's, at Oxford.
269	Fischer von Erlach, baron, of Germany.	18th	Many churches and palaces.
270	Sir John Vanbrugh of England.	—	Blenheim House; Castle Howard, Yorkshire; Eastberry, Dorset; King's Weston, near Bristol; St. John's Church, Westminster; the Opera House of the time.
270*	Filippo Ivara of Sicily.	—	Buildings near Turin on the Superga; church del Carmine; an interior staircase to the palace at Turin; employed on works in Portugal; finished cupola of Sant' Andrea, Mantua; façade of Duomo at Milan; palace of the Count Birago di Borghe at Turin, and numberless other works.
271	Colin Campbell of Scotland.	—	Wanstead House, Mereworth. Compiler of the "Vitruvius Britannicus."
272	Robert de la Cotte of France.	—	He continued the Dôme des Invalides; finished the chapel of Versailles; and raised the new buildings at St. Denys.
273	Nicholas Hawksmoor, pupil to Wren, of England.	—	Designed the church of St. George, Bloomsbury, and St. Anne, Limehouse.
274	Alexander Jean Baptiste le Blond of France.	—	L'Hôtel de Vendome, in the Rue d'Enfer at Paris. He was employed much in Russia by Peter the Great.
275	Galilei, Alessandro, of Italy.	—	Corsini Chapel, &c., Rome.
276	Galli da Bibiena of Italy.	—	Theatre Verona; theatre at Vienna. Author of two books on Architecture

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No. in Gloss.	Name of Architect.	Century.	Principal Works.
277	Gabriel, Jaques, of France.	18th.	Buildings at Bordeaux, Rennes, Paris, &c.
278	James, John, of England.	—	St. George's, Hanover Square.
279	Leoni Giacomo of Italy.	—	Lyme Hall.
280	Germain de Boffrand of Nantes, of France.	—	Much employed in Paris and Germany.
281	James Gibbs of Scotland.	—	Radcliffe's Library, Oxford; the new church in the Strand; St. Martin's-in-the-Fields; King's College, Royal Library, and Senate House, Cambridge.
282	William Kent of England.	—	Temple of Venus at Stowe; Earl of Leicester's house at Holkham; staircase at Lady Isabella Finch's in Berkeley Square; and other works.
283	Ripley, Thomas, of England.	—	Houghton Hall; Admiralty
284	Edmund Bouchardon of France.	—	Many buildings at Paris.
285	Labelye, Charles, of Switzerland.	—	Westminster Bridge.
286	Sacchetti, Giambattista, of Turin.	—	Royal Palace, Madrid.
287	Burroughs, Sir James, of England.	—	Senate House, Cambridge.
288	Jean Nicholas Servandoni of France.	—	Part of the church of S. Sulpice at Paris; many theatres and decorations for theatres at different places.
289	Ware, Isaac, of England.	—	Foot's Cray, &c. Edited a version of Palladio.
290	Dance, George, of England.	—	Mansion House, London; and other works.
291	Vanvitelli, Luigi, of Italy.	—	Palace at Caserta, &c.
292	Jacques, François Blondel, of Rouen, of France.	—	Royal abbey of St. Louis; a street and square opposite to the cathedral at Rouen; many other works both there and at Strasburg.
293	Earl of Burlington of England.	—	Chiswick House; Burlington House, Piccadilly; and other works.
294	John Brettingham of England.	—	Holkham Hall in Norfolk, finished by, in 1764.
295	Fuga, Ferdinando, of Italy.	—	Palazzo Corsini, &c., Rome, Naples, &c.
296	Simonetti, M. Aug., of Italy.	—	The Museo Pio Clementino in the Vatican.
297	Gabriel, J. A., of France.	—	Ecole Militaire and Garde Meuble, Paris.
298	John Rodolphe Perronet of France.	—	Director of the bridges and roads of France, bridge of Neuilly, and many others.
299	Jacques Germain Soufflot of France.	—	Hospital at Lyons; exchange, concert-room, and theatre in the same city; portal, nave, and towers of the church of St. Geneviève.
300	Sir William Chambers of England.	—	Somerset House, and many other works.
301	Robert Adam of England.	—	Architect to Geo. III.; author of a work on the ruins of Spalatro; his principal wosks are the Register Office at Edinburgh; infirmary at Glasgow; the Edinburgh University; Luton House; Adelphi Terrace.

AFTER CHRIST.			
No. in Gloss.	Name of Architect.	Century.	Principal Works.
302	Sir Robert Taylor of England.	18th.	Parts of Bank of England now taken down, and a great number of buildings in this country.
303	Paine, James, of England.	—	Mansion House, Doncaster; Wardour Castle; Worksop. Designs published.
304	Louis of France.	—	Theatre at Bordeaux, &c.
305	Antoine, Jacques Denis, of France.	—	The Mint, Paris; ditto at Berne, &c.
306	Ledoux, Claude Nicholas, of France.	—	Barrières at Paris; Hôtel Thelusson, &c.; and author of a splendid work on architecture.
307	Holland, Henry, of England.	—	Carlton House; old Drury Lane, &c.
308	Bonomi, Joseph, of Italy.	—	Roseneath; alterations at Riddlestone, &c.
309	Legrand, Jacq. Guill., of France.	—	Theatre Feydeau, Paris; many architectural works, &c.
310	Langhans, C. G., of Germany.	—	Brandenburg Gate, &c, Berlin.
311	Mylne, Robert, of Scotland.	—	Blackfriars Bridge; Inverary Castle, &c.
312	Gondouin, Jaques, of France.	—	Ecole de Médécine, Paris.
313	Fischer, Karl, of Germany.	—	Theatre, &c., Munich.
314	Dance, George, of England.	—	Newgate; St. Luke's Hospital.
315	Gandon, James, of Ireland.	—	Custom House, Exchange, Four Courts, &c., Dublin.
316	Soane, Sir John, of England.	—	Bank of England; Board of Trade; State Paper Office.
317	Percier, Charles, of France.	—	Architect of the Tuilleries; restorations, &c. at Louvre and Tuilleries; Chapelle Expiatoire. Author of Recueil de Decorations.

Architecture. The art of building according to certain proportions and rules determined and regulated by nature and taste. As the art, in its various parts, is the subject of this work, we do not here consider further definition necessary. For origin and progress, see Book I. Chap. I. Sect. 2.; different species at early period, Book I. Chap. I. Sect. 3.

Architecture, Arabian or Saracenic, Book I. Chap. II. Sect. 10.
——— Babylonian, Book I. Chap. II. Sect. 3.
——— British, Early Period, Book I. Chap. III. Sect. 1.
——— Byzantine and Romanesque, Book I. Chap. II. Sect. 14.
——— Celtic and Druidical. See Druidical.
——— Cyclopean. See Pelasgic.
——— Chinese, Book I. Chap. II. Sect. 8.
——— Druidical and Celtic, Book I. Chap. II. Sect. 1.
——— Egyptian, Book I. Chap. II. Sect. 7.
——— Early English, Book I. Chap. III. Sect. 3.
——— Elizabethan, Book I. Chap. III. Sect. 6.
——— Etruscan, Book I. Chap. II. Sect. 12.
——— French, Book I. Chap. II. Sect. 17.
——— Florid English or Tudor, Book I. Chap. III. Sect. 5.
——— of George I., Book I. Chap. III. Sect. 8.
——— of George II., Book I. Chap. III. Sect. 9.
——— of George III., Book I. Chap. III. Sect. 10.
——— German, Book I. Chap. II. Sect. 18.
——— Grecian, Book I. Chap. II. Sect. 11.
——— Indian, Book I. Chap. II. Sect. 6.
——— Italian, Book I. Chap. II. Sect. 16.
——— James I. to Anne, Book I. Chap. III. Sect. 7.

ARCHITECTURE, JEWISH, Book I. Chap. II. Sect. 5.
———— MEXICAN, Book I. Chap. II. Sect. 9.
———— NORMAN, Book I. Chap. III. Sect. 2.
———— ORNAMENTED ENGLISH, Book I. Chap. III. Sect. 4.
———— PELASGIC and CYCLOPEAN, Book. I. Chap. II. Sect. 2.
———— PERSEPOLITAN, Book I. Chap. II. Sect. 4.
———— POINTED, Book I. Chap. II. Sec. 15.
———— ROMAN, Book I. Chap. II. Sect. 13.
———— RUSSIAN, Book I. Chap. II. Sect. 20.
———— SPAIN and PORTUGAL, Book I. Chap. II. Sect. 19.

ARCHITECTURE, WORKS ON. It would too far extend this work to print a list of these, but we here insert

A Catalogue of the principal and most useful Works to the Student of Architecture, arranged under the several Classes of

1. GRECIAN ARCHITECTURE.
2. ROMAN ARCHITECTURE.
3. MISCELLANEOUS, ON ANCIENT ARCHITECTURE.
4. GOTHIC ARCHITECTURE.
5. MODERN FOREIGN ARCHITECTURE.
6. MODERN ENGLISH ARCHITECTURE.
7. RURAL ARCHITECTURE.
8. THEATRES.
9. BRIDGES.
10. ELEMENTARY AND PRACTICAL WORKS.
11. ORNAMENTS.

I. GRECIAN ARCHITECTURE.

Aberdeen's, Earl of, Inquiry into the Principles of Beauty in Grecian Architecture. 8vo. London, 1822.

Aikin's, E., Essay on the Doric Order. Imperial folio. London, 1810.

Antiquities (the unedited) of Attica, comprising the Architectural Remains of Eleusis, Rhamnus, Sunium, and Thoricus. By the Society of Dilettanti, and edited by Wilkins, Gandy Deering, and Bedford. Imperial folio, 79 plates. London, 1817.

Antiquities of Ionia, by Chandler, Revett, and Pars. Imperial folio, plates, 2vols., London, 1817-23.

Chambers's Civil Architecture. Gwilt's Edition. Introductory Essay on Grecian Architecture. Imp. 8vo. London, 1825.

Chandler's, R., Travels in Asia Minor and Greece. 2 vols. 4to. London, 1817.

Choiseul, Gouffier. Voyage Pittoresque de la Grèce. 2 vols. folio. Paris, 1782—1809.

Cockerell's, C. R., Temple of Jupiter Olympius at Agrigentum. London, 1825.

Delagardette. Les Ruines de Pæstum, ou Posidonia. Royal folio. Paris, 1799.

Donaldson. Collection of the most approved Examples of Doorways from ancient Buildings in Greece and Italy. 2 vols. 4to. London, 1833.

Gartner, F. Monuments of Greece and Sicily. Folio. Munich, 1819.

Harris and Angell. Temple of Selinus. Large 4to. plates. London, 1826.

Hittorff. Architecture Antique de la Sicile. Paris, 1825-30-37.

Le Roy. Les Ruines, les plus beaux Monuments de la Grèce, considerées du Coté de l'Histoire, et du Coté de l'Architecture. Imp. folio, plates by Le Bas. Paris, 1758. Not a correct work.

Major, T. Ruines de Pæstum. 24 plates, large folio. 1768.

Quincy's, M. Quatremère de, Jupiter Olympien. Large folio, plates, some coloured. Paris, 1815.

——— Restitution des Deux Frontons du Temple de Minerve à Athènes. 4to. 3 plates, Paris, 1825.

Stanhope, J. S. Olympia; or Topography of the ancient State of the Plain of Olympia, and of the Ruins of the City of Elis. Imp. folio. London, 1824.

Stuart's, James, Antiquities of Athens. 4 vols. large folio. 1762, &c.

Stuart, James, F.R.S. F.S.A., and Nicholas Revett's Antiquities of Athens, a second edition, with a very considerable augmentation of notes of subjects further elucidated and brought to light by Travellers since the times of Stuart and Revett, edited by W. Kinnaird, architect, with an additional and entirely new volume (as supplement) of Architecture and Antiquities in Greece, Sicily, &c., the result of recent Travels and Investigations, by C. R. Cockerell, W. Kinnaird, T. L. Donaldson, W. Jenkins, and others, architects. 4 vols. royal folio, about 200 plates. 1825—1830.

The plates in the three first volumes of this edition are from the coppers of the French edition.

Visconti, Chevalier. Ouvrages de Sculpture du Parthenon. 8vo. Paris, 1818.

Wilkins, W. Antiquities of Magna Græcia. Imp. folio. Cambridge, 1807. An ill-drawn work.

——— Topography and Buildings of Athens. Royal 8vo., plates. 1816.

II. Roman Architecture.

Adams, Robert. Ruins of the Palace of the Emperor Diocletian at Spalatro in Dalmatia. Folio, 61 plates. London, 1764.

Allason, T. Picturesque Views of the Antiquities of Pola. Folio, 14 plates. London, 1817.

Bartoli, P. S. Gli Antichi Sepolchri ovvero Mausolei Romani ed Etruschi. Folio, 110 plates. Roma, 1727.

——— Colonna Trajana, a P. Bellori. 128 plates.

Bellonii, J. P. Veteres Arcus Augustorum Triumphis insignes ex Reliquiis quæ Romæ adhuc supersunt per J. J. de Rubeis. Folio. Roma, 1690.

Bianchi di Lugano, P. Osservazioni sull' Arena, e sul Podio dell' Anfiteatro Flavio. Folio. Roma, 1812.

Bianconi, G. L. Descrizione dei Circhi. Folio, 20 plates. Roma, 1789.

Cameron's Baths of the Romans explained and illustrated. Folio, 75 plates. London, 1772.

Caristie. Plan et Coupe d'une partie du Forum Romain et des Monumens sur la Voie Sacrée. Atlas folio. Paris, 1821.

Castell's Villas of the Ancients illustrated. Large folio. 1728.

Ciampini, J. Rom. Vetera Monumenta. Romæ, 1747.

Cipriani, G. B. Monumenti di Fabbriche Antiche. 4to. Roma, 1796.

Desgodetz, A. Edifices de Rome, dessinées et mésurés très exactement. Folio, upwards of 300 plates. Paris, 1682.

Gell, Sir W., and J. P. Gandy. Pompeiana; the Topography, Edifices, and Ornaments of Pompeii. 2 vols. imperial 8vo. London, 1824.

Grangent, M. M., C. Durand, et S. Durant. Description des Monumens Antiques du Midi de la France. Folio, plates. Paris, 1819.

Haudebourt, L. P. Le Laurentin; Maison de Campagne de Pliné le Jeune. Large 8vo. plates. Paris, 1838.

Labacco, Ant. Appartenente all' Architettura nel qual si figurano alcune notabili Antiquità di Roma. Plates, folio. Roma.

Maffei, Scipio. History of Ancient Amphitheatres. Translated by Gordon. 8vo. London, 1730.

Mazois. Ruines de Pompeii. Paris, 1830.

Nibby, Ant. Del Foro Romano, della Via Sacra, dell' Anfiteatro Flavio, e di Luoghi adjacenti. 8vo. Roma, 1819.

Palladio, A. I Quattro Libri d'Architettura; whereof the last book is of ancient Roman Architecture. Several editions published at Venice. Figures on wood blocks.

——— Il Tempio di Minerva in Assisi confrontato colle Tavole di Giov. Antolini. Folio. Milano, 1803.

——— Les Termes des Romains dessinées. Par O. B. Scamozzi, d'apres l' Exemplaire du Lord Burlington. Folio. Vicenza, 1785.

Piranesi, Giov. Bapt. The works of (the son) subsequent to the death of John Baptist Piranesi. 29 vols. imperial folio, and double elephant folio. An abbreviated list of them is subjoined: —

- Vol. 1. Ruins of ancient Edifices of Rome, with the Explanation, Aqueducts, Baths, the Forum, &c. &c.
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Vol. 29. Antiquities of Pompeii and Herculaneum, &c. &c.

Ponce. Description des Bains de Titus. Folio, plates. Paris, 1786.

Taylor, G. L., and Edward Cresy. Architectural Antiquities of Rome. 2 vols. folio. London, 1820—1822.

Valadier, Gius. Raccoltà delle più insigni Fabbriche di Roma Antica e sui Adjacenze, illustrata con Osservazioni Antiq. da F. A. Visconti, ed incise da V. Feoli. Plates. Rome, 1810—26.

Vandoyer, A. L. T. Description du Théâtre de Marcellus à Rome. 4to. Paris, 1812.

Vasi, Giuseppe. Magnificenze di Roma Antica e Moderna. 3 vols. Roma, 1747.

Wood's Ruins of Balbec and Palmyra. 2 vols. folio. London, 1753—1757.

III. Miscellaneous.

Agincourt, D', Seroux. Histoire de l'Art par les Monumens. 6 vols. folio. Paris, 1823.

Arundale's Illustrations of the Buildings and Antiquities of Jerusalem, &c., with a Tour in Syria and Egypt. Plates, 4to. London, 1838.

Belgrado. Architettura Egiziana; Dissertazione d' un Correspondente dell' Academia delle Scienze de Parigi. 4to. Parma, 1786.

Cassas. Voyage Pittoresque de la Syrie, de la Phenicie, de la Palestine, et de la Basse Egypte. 2 vols. folio.

Coote, Architecture Arabe; ou Monument de Caire. Paris, 1824, &c.

Coussin. Genie de l'Architecture. 4to. 60 plates. Paris.

Daniel's Oriental Scenery. 9 vols. folio. London, 1813.

David. Antiquités Etrusques, Grecques, et Romaines. 5 vols. avec explications par d'Hancarville. Paris, 1787.

Denon's Egypt. Reprinted in London.

Durand, J. N. L. Recueil et Parallèle des Edifices de tout Genres, anciens et modernes. Elephant folio, 90 plates, and 8vo.: text by Legrand. Paris, 1801—1809.

Gau, F. C. Antiquités de la Nubie; ou Monumens inédits des Bords du Nil, situés entre la Première et la Seconde Cataracte. Folio. Paris, 1824-5.

Girault de Prangey. Monumens Arabes et Moresques de Cordoue, Seville, et Grenada. Large folio. Paris, 1840.

Jones, Owen, and J. Goury's Plans, Elevations, and Sections of the Alhambra. Folio. London, 1838—1840.

Langles, L. Monumens, anciens and modernes, de l'Hindostan. 2 vols. folio. Paris, 1818.

Montfauçon, Bernard de. L'Antiquité expliquée et representée en Figures. 5 vols. folio; Supplement, 5 vols. folio, 964 plates. Paris, 1729—1733

Murphy's, J., Plans, Elevations, Sections, and Views of the Batalha. Large folio, plates. London, 1836.

——— Arabian Antiquities of Spain. Atlas folio, 97 plates. London, 1828.

Quincey, Quatremère de. L'Architecture Egyptienne considerée. 18 plates, 4to. Paris, 1803.

Rich's Ruins of Babylon. 8vo. London.

Tournefort's Voyage into the Levant. 2 vols. 4to. 1718.

Winckelman. Rémarques sur l'Architecture des Anciens. 8vo. Paris, 1783.
——— Histoire de l'Art chez les Anciens. 3 vols. 4to. Paris, 1790.
——— Monumenti Antichi inediti. 2 vols. folio, 184 plates. Napoli, 1820.

IV. Gothic Architecture.

Archæologia. A work consisting of many vols. published by the Society of Antiquaries. It contains several essays on Gothic and English architecture, and subjects connected with it, as well as on ancient and modern architecture; but, as the society are not responsible for the lucubrations which appear in it, and the papers published are therefore merely to be considered as the opinions of their writers, there are extremely few on which a student could rely with safety; and we have therefore mentioned it as a work in which it is possible some points may be found valuable for his perusal; but this opinion is confined exclusively to the art in which we have presumed that we ourselves possess some small information; many of the historical and other articles in it being of great value.

Bardwell, W. Temples, ancient and modern; or, Notes on Church Architecture. Large 8vo. London, 1837.

Bentham, J. History and Antiquities of the Church at Ely. 4to. 1771.

——— Essay on Gothic Architecture. 8vo.

Blore. Monumental Remains of noble and eminent Persons. Imp. 8vo. London, 1826.

Britton. Cathedrals, comprising Canterbury, York, Salisbury, Norwich, Oxford, Winchester, Litchfield, Hereford, Wells, Exeter, Worcester, Peterborough, Gloucester, and Bristol. 4to. 1835.

As respects the graphic part of this work, it is one of great value to the student.

Britton, J. Architectural Antiquities of Great Britain. 4 vols. 4to. London, various dates.

——— Chronological and Historical Illustrations of the ancient Ecclesiastical Architecture of Great Britain. 4to. London, 1835.

——— History and Antiquities of Bath Abbey. Royal 8vo.

——— History and Antiquities of Radclyffe Church. 4to.

Britton and Brayley. History of the ancient Palace and late Houses of Parliament at Westminster. 8vo. London, 1836.

Boisserée, Sulpice. Vues, Plans, Coupes, et Détails de la Cathèdrale de Cologne, &c. Very large folio. Stutgard, 1827.

Carter, J. Ancient Architecture of England. 2 vols. folio, 1837.

Caveler, W. Select Specimens of Gothic Architecture. 4to. 80 plates. London, 1839.

Cotman, J. S. Architectural Antiquities of Norfolk. Folio, 60 plates.

——— Architectural Antiquities of Normandy. 2 vols. folio, 1820-1.

Cresy, Edw., and G. L. Taylor. The Architecture of the Middle Ages at Pisa, from Drawings and Measurements in 1817, accompanied by descriptive Accounts of their History and Construction. Imp. 4to. London, 1828-9.

Dallaway, Rev. James. Observations on English Architecture. Roy. 8vo. Lond. 1806.

——— Notices of ancient Church Architecture in the Fifteenth Century. 4to. 1824.

——— Discourses on Architecture. 8vo, London, 1833.

Ducarel. Anglo-Norman Antiquities. Plates, folio.

Dugdale, W. History of St. Paul's Cathedral in London. Folio, 1688.

Gage, J. History and Antiquities of Hengreave in Suffolk. Royal 4to. plates, 1822.

Gough. Sepulchral Monuments in Great Britain. Folio, 5 vols. London, 1796.

Grose, Captain. Essay on Gothic Architecture. 8vo.

Habershon, M. Ancient half-timbered Houses of England. 4to. London, 1836.

Halfpenny, J. Gothic Ornaments in the Cathedral of York. 4to. 105 plates, 1795.

——— Fragmenta Vetusta; or, Remains of ancient Buildings in York. Royal 4to. 34 plates, 1807.

Hall, Sir J. Essay on the Origin, History, and Principles of Gothic Architecture. 4to. 59 plates, 1813.

Hawkins, J. S. Origin and Establishment of Gothic Architecture. Plates, large 8vo. 1813.

King's Monumenta Antiqua. 4 vols. folio, plates. London, 1799.

Langlois, E. H. Description Historique des Maisons de Rouen. 8vo. with plates. Paris, 1821.

Lusson, A. L. Specimen d'Architecture Gothique; ou Plans, Coupes, Elévations de la Chapelle du Château de Neuville. Folio, 17 plates. Paris, 1839.

Mackenzie and Pugin. Specimens of Gothic Architecture, consisting of Doors, Windows, Buttresses, Pinnacles, &c. 4to. 62 plates.

Milan. Nuovo Descrizione del Duomo di Milano, &c. 8vo. plates. Milano, 1820.

Miller, G. Description of the Cathedral Church of Ely, with some Account of the Conventual Buildings. 1808.

Milner, J. Treatise on the Ecclesiastical Architecture of England. Royal 8vo. plates. London, 1835.

Moller, G. Monumens de l'Architecture Allemande. Folio, Darmstadt, 1836.

Pugin, A. Specimens of Gothic Architecture, selected from various ancient Edifices in England. 4to. plates, 2 vols. London, 1823.

——— Examples of Gothic Architecture. 3 vols. 4to. 224 plates. London, 1836.

——— Examples of Gothic Ornaments. 4to. 90 plates, 1839.

——— Examples of Gothic Gables. 4to. 30 plates, 1839.

——— Specimens of Anglo-Norman Architecture. 4to. 80 plates, 1826.

Shaw, H. Series of Details of Gothic Architecture, selected from various Cathedrals, Churches, &c. Folio. London, 1823.

Smith, J. Specimens of ancient Carpentry. 4to. 36 plates.

Vetusta Monumenta: published by the Society of Antiquaries of London. 6 vols. large folio.

Warton, Rev. T. Essay on Gothic Architecture. 8vo.

Whittington, G. D. Ecclesiastical Antiquities of France. Large 8vo. London, 1811.

Wild. Cathedral Church of Lincoln. 4to. London, 1838.

Willement, T. Regal Heraldry. London, 1821.

Winkles, B. English Cathedrals. 2 vols. London, 1837.

Woolnoth. Ancient Castles. 2 vols. large 8vo. London, 1825.

V. MODERN FOREIGN ARCHITECTURE.

Blondel, J. B. Plan, Coupe, Elévation, et Détails, du nouveau Marché St. Germain. Folio. Paris, 1816.

Bonanni, P. P. Templi Vaticani Historia. Folio. Romæ, 1696.

Brogniart, A. T. Plans du Palais de la Bourse de Paris et du Cimétière Mont Louis. Folio. Paris, 1814.

Callet et Lesueur Architecture Italienne; ou Palais, Maisons, et autres Edifices d'Italie.

Cicognara, L. Le Fabbriche più cospicue di Venezia, misurate, illustrate, ed intagliate. 2 vols. large folio. Venez. 1815.

Clochar, P. Palais, Maisons, et Vues d'Italie. Folio, 102 plates. Paris, 1809.

Costa, G. Delizie del Fiume Brenta, espresse ne' Palazzi e Casini situate sopra le sue Sponde. Folio. Venezià, 1750.

Dumont. Œuvres d'Architecture; contenant les Détails de St. Pierre de Rome. Folio. Paris.

Duval. Fontaines de Paris. Folio. Paris.

Fontana, C. Templum Vaticanum, et ipsius Origo. Folio. Romæ, 1694.

Gauthier, M. P. Les plus beaux Edifices de la Ville de Gênes et de ses Environs. Folio. Paris, 1824—1830.

Grandjean de Montigny et A. Famin. Architecture Toscane. Folio, 73 plates. Paris, 1837.

Gwilt, Joseph. Notices of the Buildings of Architects of Italy. 8vo. London, 1818.

Hittorff, J., et L. Zanth. Architecture Moderne de la Sicile. Imperial folio. Paris, 1825—1839.

Klenze, L. Von Sammlung Architectonischer Entwurfe. Folio. Munchen.

Krafft, J. C. Recueil d'Architecture civile, contenant les Plans, Coupes, et Elévations des Châteaux, Maisons de Campagne, et Habitations rurales. Folio. Paris, 1809.

Legrand, J. G., et C. F. Landon. Description de Paris et de ses Edifices. 2 vols. Paris, 1806.

Letarouilly, P. Edifices de Rome Moderne. Folio. Paris, 1829.

Moisy, M. Fontaines de Paris, anciennes et nouvelles, par Duval. Folio, 59 plates. Paris, 1812.

Palladio, A. Les Batimens et Désseins recueillés et illustrés, par Ottavio Bertotti Scamozzi. In French and Italian. 4 vols. folio. Vicenza, 1787.

——— L'Architectura di. Venezia, 1642.

Patte, P. Etudes d'Architecture. 4to. plates. Paris, 1755.

Pieraccini, F. La Piazza del Granduca di Firenze co' suoi Monumenti. Folio, plates. Firenze, 1830.

Percier et Fontaine. Choix des plus celèbres Maisons de Plaisance de Rome et de ses Environs. Folio. Paris, 1824.

Rossi, G. J. Raccoltà di Fontane nel alma Città di Roma, Tivoli, e Frascati. 4to. Rome.

Sanmichele, M. Porte di Città e Fortezze, Depositi sepolchrali, ed altre principali Fabbriche pubbliche ed private, da F. Albertolli. Imperial folio. Milan, 1815.

Schinkel. Sammlung Architectonischer Entwurfe. Large oblong folio. Berlin, 1819—1838.

Suys, F. T., et L. P. Handebourt. Palais Massimi à Rome; Plans, Coupes, Elévations, Profiles, Voutes, Plafonds, &c. 43 plates. Paris.

VI. Modern English Architecture.

Adam, W. Vitruvius Scoticus; a Collection of public and private Buildings in Scotland. Folio, 160 plates. Edinburgh.

Brettingham, M. Plans, Elevations, and Sections of Holkham, in Norfolk. Folio, 1763.

Campbell's, C., Vitruvius Britannicus. 5 vols. folio; the two last being a Continuation by Woolfe and Gandon. 1731—1771.

Chambers's, Sir W., Plans, Elevations, Sections, &c. of the Gardens and Buildings at Kew. London, 1757.

Gibbs's, J., Book of Architecture, containing St. Martin's Church. Large folio. London, 1728.

——— Designs for the Radclyffe Library. Folio. London, 1747.

Goldicutt, J. Heriot's Hospital, Edinburgh, the Design of Inigo Jones. Folio, 8 plates. London, 1828.

Jones, Inigo. Designs for public and private Buildings, by Kent. Folio. London, 1770.

Lewis, James. Original Designs in Architecture, consisting of Plans, Elevations, and Sections of various public and private Buildings in England and Ireland. 2 vols. folio, 61 plates, 1780—1797.

Mitchell, R. Plans and Views in Perspective, with Descriptions of Buildings erected in England and Scotland. Folio, 18 plates, 1801.

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Richardson, G. New Vitruvius Britannicus. 2 vols. folio. London, 1802.

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Architecture Rurale, Théorique et Pratique, à l'Usage des Propriétaires et des Ouvriers de la Campagne. 8vo. 11 plates. Toulouse, 1820.

Aikin, E. Designs for Villas and other Rural Buildings. 4to. London, 1835.

Gandy, J. Rural Architect, consisting of various Designs for Country Buildings. 4 to. 42 plates. London, 1805.

——— Designs for Cottages, Cottage Farms, and other Buildings; including Entrance Gates and Lodges. 4to. 43 plates. London, 1805.

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——— Supplement to Cottage Architecture. London, 1835.

Krafft, J. C. Plans des plus beaux Jardins Pittoresques de France, d'Angleterre, et d'Allemagne, et des Edifices, Monumens, Fabriques, &c., qui concourent à leur Embellissement, dans tous les Genres d'Architecture. 2 vols. oblong 4to. Paris, 1809.

Loudon, J. C. Encyclopædia of Cottage, Farm, and Villa Architecture. 8vo. London, 1839.

Malton, J. Essay on British Cottage Architecture. Large 4to. London, 1804.

Morel-Vindé, le Vicomte de. Essai sur les Constructions Rurales Economiques; contenant leurs Plans, Coupes, Elevations, Détails, et Devis. Folio. Paris, 1824.

Normand, C. Recueil varié de Plans et de Façades Motifs pour des Maisons de Ville et de Campagne. Folio, 53 plates. Paris, 1815.

Papworth, J. B. Rural Residences; a Series of Designs for Cottages, decorated Cottages, small Villas, &c. London, 1832.

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——— Designs for Ornamental Villas. 4to. London, 1837.

——— Designs for Village Architecture. 4to. London, 1837.

——— Designs for Farm Buildings. 4to. London, 1837.

Soane, J. Sketches in Architecture; containing Plans and Elevations of Cottages, Villas, and other useful Buildings. Folio, 43 plates. London, 1798.

VIII. Theatres.

Arnaldi, Conte Enea. Idea di un Teatro nelle principali sue Parti simile a' Teatri Antichi all' Uso moderno accomodato. 4to. Vicenza, 1762.

Beccega, T. C. Sull' Architettura Greco-Romana applicata alla Costruzione del Teatro moderno Italiano e sulle Macchine Teatrali. Folio. Venezia, 1817.

Bonnet, A., et J. A. Kaufmann. Architectonographie des Théâtres de Paris, ou Parallèle

Historique et Critique de ces Edifices, considerés sous le Rapport de l'Architecture et de la Décoration. 2 vols. 8vo. 4 atlas of plates. Paris, 1837.

Borgnis, J. A. Des Machines Imitatives et des Machines Teatrales. 4to. 27 plates. Paris, 1820.

Boullet. Essai sur l'Art de construire les Théâtres, leurs Machines, et leurs Mouvemens. 4to. plates. Paris, 1801.

Descrizione del Nuovo Sipario dell' Imperiale Regio Teatro della Scala in Milano. Small folio. Milano, 1821.

Dumont. Parallèle de Plans des Salles de Spectacle d'Italie et de France, avec des Détails de Machines Teatrales. Imperial folio, 61 plates. Paris, 1774.

Fontanesi, C. F. Decorations for Theatres; or Designs for Scene Painters. Oblong folio, 24 plates, 1813.

Galliari. Décorations de Théâtre. Folio, 24 plates. Milan.

Giorgi Felice. Descrizione Istorica del Teatro di Tor di Nino. 4to. 9 plates. Rome, 1795.

Landriani, P. Osservazioni sui Defetti prodotti nei Teatri dalla cattiva Costruzione del Palio Scenico, e su alcune Inavvertenze nel dipingere le Decorazioni. 4to. 9 plates. Milano, 1815.

Louis, M. Salle de Spectacle de Bourdeaux. Atlas folio, 22 plates, containing plans of several other theatres. Paris, 1782.

Morelli, Cos. Pianta e Spaccato del nuovo Teatro d'Imola. Folio, 19 plates. Roma, 1780.

Patte, P. Essai sur l'Architecture Théâtrale. 8vo. Paris, 1782.

Saunders, G. Treatise on Theatres. 4to. 13 plates. London, 1790. Of little value.

Schinkel. Theatre at Hamburg. 6 plates, Berlin. 1828.

Ware, S. Remarks on Theatres, and on the Propriety of vaulting them with Brick and Stone. 8vo plates. London, 1809.

Wyatt, B. On the rebuilding of Drury Lane Theatre. 4to. plates. London, 1812.

IX. Bridges.

Anselin, N. J. B. Expériences sur la Main d'Œuvres de differens Travaux dependans du Service des Ingénieurs des Ponts et Chaussées, &c. 4to. Boulogne, 1810.

Atwood, G. Dissertation on the Construction and Properties of Arches. 4to. 1801—1804.

Aubry. Mémoire sur la Construction d'un Pont de Bois de 450 Pieds d' Ouverture d' un seul Jet, &c. 4to. Paris, 1790.

Blackfriars' Bridge. 7 plates of the machines used in its construction, and the centring of the middle arch. Oblong folio.

Boistard, L. C. Recueil sur les Ponts de Nemours, &c. 4to. 19 plates. Paris, 1822.

Emmery, H. C. Pont d'Ivry en Bois, sur Piles en Pierre, traversant la Seine près du confluent de la Marne. 2 vols. 4to. plates. Paris, 1832.

Exchaquet. Dictionnaire des Ponts et Chaussées. 8vo. 12 plates. Paris, 1787.

Gauthey. Traité de la Construction des Ponts; Mémoires sur les Canaux de Navigation, &c. publié par M. Navier. 3 vols. 4to. plates. Paris, 1816

autier, H. Traité de la Construction des Ponts et Chaussées. 8vo. Paris, 1721—1765.

oury, G. Recueil d'Observations, Mémoires, et Projets, concernant la Navigation Intérieure. 2 tomes 4to. avec un atlas de planches. Paris, 1827.

Gwilt, Joseph. On the Rebuilding of London Bridge. 8vo. with 1 plate. London, 1823.

——— Treatise on the Equilibrium of Arches. 8vo. plates. London, 1826.

The editions of a later date are spurious, being without additions or corrections by the author.

Hutton, C. Principles of Bridges. 8vo. 1772.

Le Sage, P. C. Recueil de divers Mémoires des Ponts et Chaussées. 2 tom. 4to. Paris, 1810.

Milne, J. Theory and Principles of Bridges and Piers. 8vo. 36 plates. London, 1806.

Navier. Mémoire sur les Ponts Suspendus. 4to. Paris, 1830.

Perronet, Œuvres de. 4to. plates. Atlas folio. Paris, 1793.

Polonceau, A. R. Notice sur la nouveau Système de Ponts en Fonte, suivi dans la Construction du Pont du Carousel. 4to. Atlas folio, plates. Paris, 1839.

Pont en Pierre a construire sur la Seine à Rouen. 4to. plates. Paris, 1815.

Prony, M. de. Nouvelle Architecture Hydraulique. 2 vols. 4to. plates. Paris, 1790.

Regemortes, M. de. Description du nouveau Pont de Pierre construit sur la Rivière d'Allier à Moulins. Folio. Paris, 1771.

Rondelet, A. Essai Historique sur le Pont de Rialto. 4to. plates. Paris, 1837.

Seaward, J. Observations on the Rebuilding of London Bridge. 8vo. plates. London, 1824.

Seguin, Ainé. Des Ponts en Fil de Fer. 8vo. plates. Paris, 1824.

Telford, T. Reports on the Holyhead Roads, Harbour, Bridges, &c. Folio, with plates. London, 1822.

Vicat. Description du Pont Suspendu construit sur la Dordogne à Argental. 4to. plates. Paris, 1830.

Ware, S. Treatise on the Properties of Arches, and their Abutment Piers. London 1809.

Wiebeking, Le Chevalier. Architecture Hydraulique fondée sur la Théorie et la Pratique. 4 vols. 4to. Atlas vol. of plates. Munich, 1814—1824.

X. ELEMENTARY AND PRACTICAL WORKS.

Alberti, Leo Bapt. Libri de Re Ædificatoria. Decem folio, 1st edit. Florence, 1485

——— Reprinted in 4to. Paris, 1512.

——— Translated into Italian by Pietro Lauro. Small 4to. Venice, 1546.

——— Translated into Italian by Cosimo Bartoli. Folio. Florence, 1556.

——— Translated into English by Leoni. Folio. London, 1726—1755; and Bologna, 1782.

Androuet du Cerceau. Livre d'Architecture. Folio, 50 plates. Paris, 1662.

Antoine, J. Traité d'Architecture. 4to. plates. Treves, 1768.

Aviler, d', C. A. Cours d'Architecture. 4to. Paris, 1760.

Barlow, P. Treatise on the Strength of Timber, Cast Iron, Malleable Iron, and other Materials, &c. 8vo. London, 1837.

Barozzi, Vignola di. Œuvres complètes. Folio. Paris, 1823.

——— Ordini d'Architettura Civile. 4to. 44 plates. Milano, 1814.

Bartholomew, Alfred. Specifications for Practical Architecture, preceded by an Essay on the Decline of Excellence in the Structure, and in the Science of Modern English Buildings. Large 8vo. 160 illustrations. London, 1840.

This is one of the most valuable works to the English practical architect that has ever appeared.

Blondel, J. F. Cours d'Architecture. 9 tom. 8vo. 300 plates. Paris, 1771—1777.

Borgnis, J. A. Traité Elémentaire de Construction appliquée à l'Architecture Civile. 2 tom. 4to. 30 plates. Paris, 1823.

Bruyere, L. Etudes relatives à l'Art des Constructions. Folio. Paris, 1823.

Bullet. Architecture Pratique. 8vo. plates. Paris, 1774.

——— By Mazois. Paris, 1824.

Calderari, C. Opere di Architettura. 2 tom. folio, 90 plates. Vicenza, 1800.

Chambers. Treatise on the Decorative Part of Civil Architecture, with Essay on Grecian Architecture, and other Additions by Joseph Gwilt. 2 vols. imp. 8vo. 66 plates. London, 1823.

Clerc, S. Le. Treatise on Architecture, translated by Chambers. 2 vols. 8vo. and vol. of plates. London, 1732.

Detournelle. Recueil d'Architecture. Folio, 60 plates. Paris, 1805.

Douliot, J. P. Traité special de Coupe des Pierres. 2 tom. 4to. Paris, 1825.

Durand, J. N. L. Leçons d'Architecture. 2 tom. 4to. plates. Paris, 1819.

——— Partie Graphique des Cours d'Architecture. 4to. 34 plates. Paris, 1821.

Elmes, J. On Dilapidations. 8vo. London, 1829.

Evelyn's, J., Ancient and Modern Architecture. Folio. London, 1680.

——— Parallel of Ancient and Modern Architecture: translated from R. Freart. Folio, plates. London, 1723.

Farraday, Prof. On the practical Prevention of Dry Rot in Timber. 8vo. London, 1836.

Felibien, M. Principes de l'Architecture, de la Sculpture, et de la Peinture. 4to. plates. Paris, 1697.

Frezier. Théorie et la Pratique de la Coupe des Pierres et des Bois. 3 vols. 4to. plates. Paris, 1757.

Fourneau, H. Art du Trait de Charpenterie. 4 vols. folio, 87 plates. Paris, 1820.

Gauthey, E. M. Dissertation sur les Dégradations survenues aux Piliers du Dôme du Panthéon, et sur les Moyens d'y remedier. 4to. plates. Paris, 1798.

Goldman, Architecture of, by L. C. Sturms; the text in the German language. 1714.

Gwilt, Joseph. Sciography; or Examples of Shadows, with Rules for their Projection, for the Use of Architectural Draughtsmen, and other Artists. 8vo. 24 plates. London, 1824.

——— Rudiments of Architecture, Practical and Theoretical. Royal 8vo. plates. London, 1826.

Halfpenny, W. Architecture delineated. 4to. 45 plates. London, 1749.

——— Art of Sound Building. Folio. London, 1725.

Higgins, R. Art of composing and applying Calcareous Cements, and of preparing Quicklime. 8vo. London, 1780.

Inman, W. On Ventilation, Warming, and the Transmission of Sound; with notes. London, 1836.

Krafft, J. C. Recueil d'Architecture Civile, contenant les Plans, Coupes, et Elévations des Châteaux, Maisons de Campagne, et Habitations Rurales, &c. Folio, 121 plates. Paris, 1812.

——— Traité sur l'Art de la Charpenterie; Plans, Coupes, et Elévations, de diverses Productions. Folio. Paris, 1820.

Laugier, P. Essai sur l'Architecture. 8vo. Paris, 1755.

Ledoux, E. N. L'Architecture considerée sous le Rapport de l'Art, des Mœurs, et de la Legislation. Imperial folio, plates. Paris, 1789.

L'Eveillé, C. J. Considérations sur les Frontons. 4to. Paris, 1824.

Le Grand Essai sur l'Histoire Générale de l'Architecture. 8vo. Paris, 1819.

This is the text to Durand's Paralléle.

Lorme, Philibert de. Œuvres d'Architecture. Folio, 2 vols. in 1. Paris, 1626; Rouen, 1648.

The first edition, the Treatise on Architecture, in 9 books, was published in Paris, 1567. The tenth book on Carpentry, entitled, "Nouvelles Inventions pour bien Bâtir et à petit Frais," was published in folio. Paris, 1561—1568 and 1576.

Loudon, J. C. Architectural Magazine. 5 vols. 8vo. London, 1838.

Malton, T. Complete Treatise on Perspective. Folio, 2 vols. London, 1778.

———, J. Young Painter's Maulstick. 4to. plates. London, 1806.

Mandar. Etude d'Architecture Civile; ou Plans, Elévations, Coupes, et Détails necessaires pour élever, distribuer, et décorer une Maison et ses Dependances. Imperial folio, 122 plates. Paris, 1830.

Manetti, G. A. Studio degli Ordini d'Architettura. Folio, 25 plates. Firenze, 1808.

Mesauge, M. Traité de Charpenterie et des Bois de toutes Espèces. 2 tom. Paris, 1753.

Mitford, N. Principles of Design in Architecture traced in Observations on Buildings (published anonymously). 8vo. London, 1819.

Nicholson, P. Principles of Architecture. 8vo. 3 vols. plates. London, 1836.

——— Architectural Dictionary. 2 vols. 4to. London, 1819.

——— Carpenter and Joiner's Assistant. 4to. London, 1815.

——— Carpenter's new Guide. 4to. London, 1819.

——— Practical Treatise on the Art of Masonry and Stone-cutting. 8vo. London, 1832.

Noble, J. Professional Practice of Architects, and that of Measuring Surveyors, and Reference to Builders. 8vo. London, 1836.

Normand, C. Nouveau Parallèle des Ordres d'Architecture des Grecs, des Romains, et des Auteurs modernes. Folio, 63 plates. Paris, 1819.

Nosban. Manuel du Menuisier. 2 tom. 12mo. plates. Paris, 1827.

Pasley, Col. C. W. On Limes, Calcareous Cements, Mortars, Stuccoes, Concrete, and Puzzolanas, &c. 8vo. London, 1838.

Patte, P. Mémoire d'Architecture. 4to. Paris, 1769.

Perrault, C. Ordonnance des Cinq Espèces de Colonnes. Folio. Paris, 1683.

Pozzo, Andrea. Prospettiva di Pittori, &c. 2 vols. fol. 218 plates. Roma, 1717—1737.

Price, F. British Carpenter. 4to. plates. London, 1753.

——, R. On Reversionary Payments; by Morgan. 2 vols. 8vo. London, 1803.

Rondelet, J. Traité Théorique et Pratique de l'Art de Bâtir. 5 tom. 4to. and fol. vol. of 207 plates. Paris, 1835.

——— Mémoire Historique sur le Dôme du Panthéon François. 4to. plates. Paris, 1814.

——— Mémoire sur la Réconstruction de la Coupole de la Halle au Blé de Paris. 4to. plates. Paris.

Scamozzi, V. L'Idea dell' Architettura Universale. 2 vols. fol. Venet. 1615.

Serlio, Seb., Architettura di. 4to. Venet, 1567.

Simonin. Traité Elémentaire de la Coupe des Pierres. 4to. Paris, 1792.

Sturm, L. C. Prodromus Architecturæ Goldmanniæ. Oblong folio. Nuremberg, 1714.

Tredgold, T. Elementary Principles of Carpentry, by Peter Barlow. 4to. 50 plates. London, 1840.

Toussaint, C. J. Traité de Géometrie et d'Architecture Théorique et Pratique simplifié. 4 vols. 4to. Paris, 1811-12.

Turnbull, W. Essay on Construction of Cast Iron Beams. 8vo. London, 1833.

Vitruve, traduit par C. Perrault. Folio, plates. Paris, 1684.

Vitruvii de Architectura notis Variorum a J. de Laet. Folio. Amst. 1649.

Vitruvio, l'Architettura di, tradotta ed comentata da B. Galiani. Folio. Siena, 1790.

Vitruvio, trad. et coment. da Barbaro. Folio, wood-cuts. Venezia, 1556.

Vitruvius, Architecture of, translated by J. Gwilt. Imperial 8vo. London, 1826.

Wiebeking, le Chevalier de. Architecture Civile, Théorique, et Pratique, enrichi de l'Histoire descriptive des Edifices anciennes et modernes les plus remarquables. 7 vols. 4to., 260 plates, large folio. Munich, 1823.

XI. Ornaments.

Albertolli. Corso Elementare di Ornamenti Architettonici. Folio, 28 plates. Milan, 1805.

Architectural Ornaments. A Collection of Capitals, Friezes, Roses, Entablatures, Mouldings, &c. drawn on Stone from the Antique. 100 plates. London, 1824.

Beauvallet, P. N. Fragmens d'Architecture, Sculpture, et Peinture dans le Style Antique. Paris, 1804.

Choix des Monumens les plus remarquables des Anciens Egyptiens, des Persans, des Grecs, des Volsques, des Etrusques, et des Romains, consistans en Statues, Bas-Reliefs, et Vases. 2 tom. fol. 244 plates. Rome, 1788.

Colette, J. Livre de divers Ornemens pour Plafonds, Cintres, Surbaissées, Galeries. Folio, 10 plates. Paris.

Columbani, P. Capitals, Friezes, and Cornices, &c. 4to.

Fowler, W. Collection of Mosaic, Roman and Norman tesselated Pavements and ancient stained Glass discovered in different parts of England. Elephant folio size. Published at various times.

Gli Ornati delle Pareti ed i Pavimenti delle Stanze dell' Antica Pompeia. Atlas folio, 21 plates. Napoli, 1796.

Jalembier, C. A. Principes d'Ornemens pour l'Architecture. 40 plates. Paris.

Jombert, C. A. Repertoire des Artistes; ou Recueil de Compositions d'Architecture et d'Ornemens, antiques et modernes, de tout Espèce, par divers Auteurs. 2 vols. folio. Paris, 1765.

Le Noir, A. Nouvelle Collection d'Arabesques propres à la Décoration des Appartemens dessinées à Rome par L. Poussin. 4to. Paris.

Le Pautre. Œuvres d'Architecture; contenant les Frises, Feuillages, Montans ou Pilastres, Grotesques, Moresques, Parmeaux, Placarts, Trumeaux, Lansbris, Amortissemens, Plafonds, et généralement tout ce qui concerne l'Ornement. 3 tom. folio. Paris, 1751.

Moreau, C. Fragmens, et Ornemens d'Architecture dessinés à Rome d'après L'Antique, formant un Supplément à l'Œuvre d'Architecture de Desgodetz. Large folio, 36 plates. Paris.

Normand, C. Nouveau Recueil en divers Genres d'Ornemens, et autres Objets propres à la Décoration. Folio, 46 plates, Paris, 1803.

Percier, C. et P. F. L. Fontaine. Recueil de Décorations Intérieures, comprenant tout ce qui a rapport à l'Ameublement. Folio, 72 plates. Paris, 1812.

Pergolesi. Ornaments. Large folio, 30 plates. 1777.

Piroli, T. Monumens Antiques du Musée Napoleon. 4 tom. 4to., 40 plates. Paris, 1804.

Recueil d'Arabesques; contenant les Loges du Vatican, gravées d'après Raphael et grand Nombre d' autres Compositions du même Goût dans le Style Antique. Large folio, Paris, 1802.

Tatham, C. H. Grecian and Roman Ornaments. Folio, 101 plates. London, 1825.

Volpato. Engravings of the Ornaments of the Vatican.

Vulliamy, L. Examples of Ornamental Sculpture in Architecture, containing 40 plates, imp. folio. London, 1828.

Architrave. (Gr. Αρχειν, to govern, and Lat. Trabs, a beam.) The lower of the three principal members of the entablature of an order, being, as its name imports, the chief beam employed in it, and resting immediately on the columns. It is sometimes called *Epistylium*, from επι, upon, and στυλος, a column. The height of the architrave varied in the different orders, as also in different examples of the same order. See Grecian Architecture, page 58. in the work; and, for its usual proportion, the orders from Sect. 5. to Sect. 7. Chap. I. Book III.

Architrave Cornice. An entablature consisting of an architrave and cornice only, without the interposition of a frieze. It is never used with columns or pilasters, unless through want of height. It is, however, allowable. See p. 748.

Architrave of a Door or Window. A collection of members and mouldings round either, used for the decoration of the aperture. The upper part, or lintel, is called the *traverse*, and the sides the *jambs*. See Antepagmenta.

Archivolt. (Lat. Arcus volutus.) The ornamental band of mouldings round the voussoirs, or arch-stones of an arch, which terminates horizontally upon the impost. It is decorated, as to the members, analogously with the architrave, which, in arcades, it may be said to represent. It differs in the different orders. See p. 721.

ARCHIVOLTUM. In mediæval architecture, an arched receptacle for filth. A cesspool or common sewer.

ARCHWAY. An aperture in a building covered with a vault. Usually an arched passage or gate wide enough for carriages to pass.

ARCUS ECCLESIÆ. In mediæval architecture, the arch dividing the nave of the church from the choir or chancel.

ARCUS PRESBYTERII. In mediæval architecture, the arch over the tribune marking the boundaries of its recess.

ARCUS TORALIS. In mediæval architecture, the lattice separating the choir from the nave in a basilica.

AREA. In Architecture, a small court or place, often sunk below the general surface of the ground, before windows in the basement story. It is also used to denote a small court even level with the ground.

AREA. In Geometry, the superficial content of any figure. See Section on MENSURATION, p. 372.

ARENA. The central space in a Roman amphitheatre, wherein the gladiators fought. See AMPHITHEATRE.

ARGELIUS. See ARCHITECTS, list of, 19.

ARITHMETIC and ALGEBRA. See Book II. Chap. I. Sect. 1.

ARMOURY. An apartment destined to the reception of instruments of war.

ARNOLFO. See ARCHITECTS, list of, 125.

ARONADE. Embattled; a junction of several lines forming indentations like the upward boundary of an embattled wall, except that the middle of every raised part is terminated by the convex arch of a circle, which arch does not extend to the length of that part.

ARRIS (probably abbreviated from the Ital. *a risega*, at the projection, or from the Sax. aꞃıꞅan, to arise). The intersection or line on which two surfaces of a body forming an exterior angle meet each other. It is a term much used by all workmen concerned in building, as the arris of a stone, of a piece of wood, or any other body. Though, in common language, the edge of a body implies the same as arris, yet, in building, the word *edge* is restrained to those two surfaces of a rectangular parallelopipedal body on which the length and thickness may be measured, as in boards, planks, doors, shutters, and other framed joinery.

ARRIS FILLET. A slight piece of timber of a triangular section, used in raising the slates against chimney shafts, or against a wall that cuts obliquely across the roof, and in forming gutters at the upper ends and sides of those kinds of skylights of which the planes coincide with those of the roof. When the arris fillet is used to raise the slates at the eaves of a building, it is then called the *eaves' board*, *eaves' lath*, or *eaves' catch*.

ARRIS GUTTER. A wooden gutter of this V form fixed to the eaves of a building.

ARSENAL. A public establishment for the deposition of arms and warlike stores.

ARTIFICER. (Lat. Ars and Facio.) A person who works with his hands in the manufacture of anything. He is a person of intellectual acquirements, independent of mere operation by hand, which place him above the *artisan*, whose knowledge is limited to the general rules of his trade.

ASAROTUM. In ancient architecture, a species of painted pavement used by the Romans before the invention of Mosaic work.

ASH. The Fraxinus of botanists. See TIMBER, Sect. on, p. 486.

ASHELEY. See ARCHITECTS, list of, 189.

ASHLAR OR ASHLER. (Ital. Asciare, to chip.) Common or free-stones as brought from the quarry of different lengths and thicknesses.

Also the facing given to square stones on the front of a building. When the work is smoothed or rubbed so as to take out the marks of the tools by which the stones were cut, it is called *plain ashlar*. *Tooled ashlar* is understood to be that whereof the surface is wrought in a regular manner, like parallel flutes, and placed perpendicularly in the building. But when the surfaces of the stones are cut with a broad tool without care or regularity, the work is said to be *random-tooled*. When wrought with a narrow tool, it is said to be *chiselled* or *boasted*, and when the surface is cut with a very narrow tool, the ashlar is said to be *pointed*. When the stones project from the joints, the ashlar is said to be *rusticated*, in which the faces may have a smooth or broken surface. In superior work, neither pointed, chiselled, nor random-tooled work are employed. In some parts of the country herring-bone ashlar and herring-bone random-tooled ashlar are used. See MASONRY, p. 518, *et seq*.

ASHLERING. In carpentry, the short upright quartering fixed in garrets about two feet six inches or three feet high from the floor, being between the rafters and the floor in order to make the room more convenient by cutting off the acute angle formed by the rafters.

ASPECT. (Lat. Aspicio.) The quarter of the heavens to which the front of a building faces. Thus a front to the north is said to have a north aspect.

Asphaltum. A bituminous substance found in various places and used as a building material. See Book II. Chap. II. Sect. 12.

Assemblage. The joining or uniting several pieces together, or the union of them when so joined. Carpenters and joiners have many modes of accomplishing this, as by framing, mortise and tenon, dovetailing, &c. See Practical Carpentry and Joinery, p. 538, *et seq.*

Assemblage of the Orders. The placing of columns upon one another in the several ranges. See Orders upon Orders, Book III. Chap. I. Sect. 11.

Astragal. (Gr. *Αστραγαλος*, a die, or huckle bone.) A small moulding of a semicircular profile. Some have said that the French call it *talon*, and the Italians *tondino*; but this is a mistake, for the term is properly applied only to the ring separating the capital from the column. The astragal is occasionally cut into representations of beads and berries. A similar sort of moulding, though not developed in its profile as is the astragal, is used to separate the faces of the architrave.

Atlantides. See Caryatides.

Atrium. In ancient Roman architecture, a court surrounded by porticoes in the interior part of Roman houses. According to Scaliger it is derived from the Greek *αἴθριος*, exposed to the air. By some it has been considered the same apartment as the *vestibule*, and Aulus Gellius intimates that in his time the two words were confounded. See, however, more on this head in the section on Roman Architecture in the body of the work, p. 100.

Attic, or Attic Order. (Gr. *Αττικος*, Athenian; facetiously, we supposed, derived, in the seventh edit. of Encyc. Brit. art. Architecture, from *ἄτειχον*, without a wall, which, if true, would transform all objects into attic things if detached from a wall.) A low order of architecture, commonly used over a principal order, never with columns, but usually with antæ or small pilasters. It is employed to decorate the façade of a story of small height, terminating the upper part of a building; and it doubtless derives its name from its resemblance in proportional height and concealed roof to some of the buildings of Greece. Pliny thus describes it after speaking of the other orders: "Præter has sunt quæ vocantur Atticæ columnæ quaternis angulis pari laterum intervallo." We, however, find no examples of square pillars in the remains of ancient art, though almost all the triumphal arches exhibit specimens of pilastral attics, having no capitals save the cornice breaking round them. In modern architecture the proportions of the attic order have never been subject to fixed rules, and their good effect is entirely dependent on the taste and feeling of the architect.

Attic Base. The base of a column consisting of an upper and lower torus, a scotia and fillets between them. It is thus described by Vitruvius, "it must be so subdivided that the upper part be one third of the thickness of the column, and that the remainder be assigned for the height of the plinth. Excluding the plinth, divide the height into four parts, one whereof is to be given to the upper torus; then divide the remaining three parts into two equal parts, one will be the height of the lower torus, and the other the height of the scotia with its fillets.

Attic Story. A term frequently applied to the upper story of a house when the ceiling is square with the sides to distinguish it from garrets. See Book III. Chap. I. Sect. 13.

Attributes. In decorative architecture, are certain symbols given to figures, or disposed as ornaments on a building, to indicate a distinguishing character: as a lyre, bow, or arrow to Apollo; a club to Hercules; a trident to Neptune; a spear to Pallas, &c.

Auger. A carpenter's and joiner's tool for boring large holes. It consists of a wooden handle terminated at the bottom with steel. The more modern augers are pointed and sharpened like a centre bit, the extremity of one of the edges being made to cut the wood clean at the circumference, and the other to cut and take away the core, the whole length of the radius.

Aviary. (Lat. Avis.) A house or apartment set apart for keeping and breeding birds.

Avitus, St. See Architects, list of, 58.

Aula. (Lat.) In ancient Roman architecture, a court or hall.

Awning. (Fr. Aulne.) Any covering intended as a screen from the sun or protection from the rain.

Axe. (Sax. eax.) A tool with a long wooden handle and a cutting edge situate in a plane passing longitudinally through the handle. It is used for hewing timber by cutting it vertically, the edge being employed in forming horizontal surfaces. The axe differs from the *joiner's hatchet* by being much larger, and by its being used with only one hand. Axes of various sizes, depending upon the quality of the material, are used by stone-cutters and bricklayers.

Axis. The spindle or centre of any rotative motion. In a sphere a line passing through the centre is the axis.

B.

Babylonian Architecture. See Book I. Chap. II. Sect. 3.

Back. The side opposite to the face or breast of any piece of architecture. In a recess upon a quadrangular plane, the face is that surface which has the two adjacent planes, called the sides, elbows, or gables. When a piece of timber is fixed in an horizontal or in an inclined position, the upper side is called the back, and the lower the breast. Thus the upper side of the handrail of a staircase is properly called the back. The same is to be understood with regard to the curved ribs of ceilings and the rafters of a roof, whose upper edges are always called the *backs*.

Back of a Chimney. The recessed face of it towards the apartment, &c. See Chimney.

Back of a Hand-rail. The upper side of it.

Back of a Hip or other **Rafter.** The upper side or sides of it in the sloping plane of the side of the roof.

Back Lining of a Sash Frame. That parallel to the pulley piece and next to the jamb on either side. See Joinery, p. 563, *et seq.*

Back Shutters. Those folds of a shutter which do not appear on the face being folded within the boxing. See Joinery, p. 570, *et seq.*

Back of a Stone. The side opposite to the face. It is generally rough.

Back of a Wall. The inner face of it.

Back of a Window. The piece of wooden framing in the space between the lower part of the sash frame and the floor of the apartments, and bounded at its extremities right and left by the *elbows* of the window. The number of panels into which it is framed is dependent on what may be necessary for carrying out the design; it rarely, however, consists of more than one.

Backing of a Rafter or **Rib.** The formation of the upper or outer surface of either in such a manner as to range with the edges of the rafters or ribs on either side of it. The formation of the inner edges of the ribs for a lath and plaister ceiling is sometimes called *backing*, but improperly, since contrary to the true meaning of the word.

Backing of a Wall. The filling in and building which forms the inner face of the work. In this sense it is opposed to facing, which is the outside of the wall. In stone walls the backing is unfortunately too often mere rubble, while the face is ashlar.

Badigeon. A mixture of plaster and freestone sifted and ground together, used by statuaries to repair defects in their work. The joiner applies this term to a mixture of sawdust and strong glue, with which he fills up the defects of the wood after it has been wrought. A mixture for the same purpose is made of whiting and glue, and sometimes with putty and chalk. When the first of these is used, it is allowed to remain until quite hard, after which it may be submitted to the operation of planing and smoothing. Without this precaution, it may shrink below the surface of the work.

Bagnio. (It.) An Italian term for a bath, usually applied by the English to an establishment having conveniences for bathing, sweating, and otherwise cleansing the body. It is applied by the Turks to the prisons where their slaves are confined, in which it is customary to have baths.

Baguette. (Fr.) A small moulding of the astragal species. It is occasionally cut with pearls, ribands, laurels, &c. According to M. Le Clerc, the baguette is called a *chaplet* when ornaments are cut on it.

Bailey. See Castle.

Bakehouse. An apartment provided with an oven and kneading troughs for baking.

Balaneia. A Greek term for a bath.

Balcony. (It. Balcone.) A projection from the external wall of a house, borne by columns or consoles, and usually placed before windows or openings, and protected on the extremity of the projection by a railing of balusters or ironwork. In the French theatre, the *balcon* is a circular row of seats projecting beyond the tier of boxes immediately above the pit.

Baldachino. (It.) An open building, supported by columns, and covered with a canopy, generally placed over an altar. Sometimes the baldachino is suspended from the roof, as in the church of St. Sulpice at Paris. It succeeded to the ancient ciborium, which was a cupola supported on four columns, still to be seen in many of the churches of Rome. The merit of its invention seems to belong to Bernini. That erected by him in St. Peter's is 128 feet high, and being of bronze weighs near 90 tons. It was built by order of the Pope Barberini, from the robbery of the Pantheon, and occasioned the bitter observation, "Quod non fecerunt Barbari fecerunt Barberini."

Baldwin. See Architects, list of, 104.

Balection or **Bolection Mouldings.** Mouldings which project beyond the surface of a piece of framing. See p. 569.

Balks or **Baulks.** (Dutch.) Sometimes called *dram* timber. They are pieces of whole fir, being the trunks of small trees of that species, rough-squared for building purposes. In the metropolis the term is applied to short lengths, from eighteen to twenty-five feet, mostly under ten inches square, tapering considerably, and with the angles so left that the piece is not exactly square.

Ballium. In the architecture of the middle ages, the open space or court of a fortified castle. This has acquired in English the appellation Bailey; thus St. Peter's in the Bailey at Oxford, and the Old Bailey in London, are so named from their ancient connection with the sites of castles.

Balloon. A round ball or globe placed on a column or pier, by way of crowning it. The same name is given to the balls on the tops of cathedrals, as at St. Peter's, which is 8 feet diameter, and at St. Paul's in London.

Balneum. (Lat.) A bath.

Balteus. (Lat. a girdle.) The wide step in theatres and amphitheatres, which afforded a passage round them without disturbance to the sitters. No one sat on it; it served merely as a landing-place. In the Greek and Roman theatres, every eighth step was a balteus. Vitruvius gives the rules for properly setting it out, in the third chapter of his fifth book.

The term balteus is also used by Vitruvius to denote the strap which seems to bind up the coussinet or cushion of the Ionic capital.

Baluster. A species of small column belonging to a balustrade. See Book III. Chap. I. Sect. 16. This term is also used to denote the lateral part of the volute of the Ionic capital. Vitruvius calls it *pulvinata*, on account of its resemblance to a pillow.

Balustrade. A parapet or protecting fence formed of balusters, sometimes employed for real use, and sometimes merely for ornament. For the method of designing balustrades, and other particulars relating to them, see Book III. Chap. I. Sect. 16.

Band. (Fr. Bande.) A flat member or moulding, smaller than a fascia. The face of a band is in a vertical plane, as is also that of the fascia; the word, however, is applied to narrow members somewhat wider than fillets; and the word *fascia* to broader members. The cinctures sometimes used round the shafts of rusticated columns are called bands. In this case the column is called a *banded column*.

Bandages. A term applied to the rings or chains of iron inserted in the corners of a stone wall, or round the circumference of a tower, at the springing of a dome, &c., which act as a tie on the walls to keep them together.

Bandelet, or **Bandlet.** A small band encompassing a column like a ring.

Banister. A vulgar term for baluster, which see.

Banker. A bench, on which masons prepare, cut, and square their work.

Banquet. (Fr.) The footway of a bridge when raised above the carriage-way.

Baptismal Font. A vessel raised above the ground for containing the holy water used in the administration of baptism. Many of the fonts in Saxon churches are still in being. The plans and horizontal sections are commonly circles, octagons, or squares, and at a little later dates were elaborately decorated with mouldings and sculptures.

Baptistery. (Gr. Βαπτίζω.) A building in the architecture of the middle ages, destined for administration of the rite of baptism. It has been contended by some that the baptistery was at first placed in the interior vestibules of the early churches, as are in many churches the baptismal fonts. This, however, was not the case. The baptistery was quite separate from the basilica, and even placed at some distance from it. Until the end of the sixth century, it was, beyond doubt, a distinct building; but after that period the font gradually found its way into the vestibule of the church, and the practice became general, except in a few churches, as at Florence, and in those of all the episcopal cities of Tuscany, Ravenna, of S. Giovanni Laterano at Rome, and some few other places. The last mentioned is perhaps the most ancient remaining. There was a baptistery at Constantinople, of such dimensions that, on one occasion, it held a very numerous council. That at Florence is nearly ninety feet in diameter, octagonal, and covered with a dome. It is enclosed by the celebrated bronze gates by Lorenzo Ghiberti, which Michel Angelo said were fit to be the gates of Paradise. The baptistery of Pisa, designed by Dioti Salvi, was finished about 1160. The plan is octagonal, about 129 feet in diameter and 179 feet high. See p. 118.

Bar. In a court of justice, an enclosure, three or four feet high, in which the counsel have their places to plead causes. The same name is given to the enclosure, or rather bar before it, at which prisoners are placed to take their trials for criminal offences.

Bar. A piece of wood or iron used for fastening doors, window shutters, &c.

Bar of a Sash. The light pieces of wood or metal which divide a window sash into compartments for the glass. The *angle bars* of a sash are those standing at the intersection of two vertical planes.

Bar Iron is that made of the metal of sows and pigs, as it comes from the furnace. The sows and pigs, as they are technically termed, pass through the forges and chaufery, where, having undergone five successive heats, they are formed into bars. See Sect. 5.

Book II. Chap. II. For the weight of a foot of bar iron of different thicknesses, see p. 590.

BAR-POSTS. Posts driven into the ground for forming the sides of a field gate. They are mortised. to admit of horizontal bars being put in or taken out at pleasure.

BARBACAN. A watch-tower for descrying an enemy: also the outer work or defence of a castle, or the fort at the entrance of a bridge. Apertures in the walls of a fortress, for firing through upon the enemy, are sometimes called by this name. The etymology of the word has been variously assigned to French, Italian, Spanish, Saxon, and Arabian origin. See CASTLE.

BARGE BOARDS. The inclined projecting boards placed at the gable of a building, and hiding the horizontal timbers of a roof. They are frequently carved with trefoils, quatrefoils, flowers, and other ornaments and foliage.

BARGE COUPLES. (Sax. Býꞃᵹan, to bar.) Two beams mortised and tenoned together for the purpose of increasing the strength of a building.

BARGE COURSE. The part of the tiling which projects over the gable of a building, and which is made good below with mortar.

BARN. (Sax. Beꞃn.) A covered farm-building for laying up grain, hay, straw, &c. The situation of a barn should be dry and elevated. It is usually placed on the north or north east side of a farm-yard. The barns, outhouses, and stables should not be far distant from each other. They are most frequently constructed with wooden framing of quarters, &c., and covered with weather boarding; sometimes, in superior farms, they are built of stone and brick. The roofs are usually thatched or tiled, as the materials for the purpose are at hand; but as the grain should of all things be kept dry, to prevent it from moulding, the gable ends should be constructed of brick, and apertures left in the walls for the free admission of air. The bays, as they are called, are formed by two pairs of folding doors, exactly opposite to each other, and, as well as for thrashing, afford the convenience of carrying in and out a cart or waggon load of corn in sheaves, or any sort of bulky produce. The doors in question must be of the same breadth as the threshing-floor, to afford light to the threshers, and air for winnowing the grain. It is a good practice to make an extensive penthouse over the great doors sufficiently large to cover a load of corn or hay, in case of the weather not permitting it to be immediately housed.

BAROZZI DA VIGNOLA. See ARCHITECTS, list of, 217.

BARRACKS. See Book III. Chap. III. Sect. 19.

BARREL DRAIN. One in the form of a hollow cylinder.

BARYCÆ OF BARYCEPHALÆ. (Gr. *βαρυς*, low or flat, and Κεφαλη, head.) The Greek name for an aræostyle temple.

BASE. (Gr. *βασις*.) In geometry, the lower part of a figure or body. The *base of a solid* is the surface on which it rests.

BASE OF A COLUMN. The part between the shaft and the pavement or pedestal, if there be any to the order. Each column has its particular base, for which see Sections 3 to 7. on the orders. For the Attic base see under that word.

BASE OF A ROOM. The lower projecting part. It consists of two parts, the lower whereof is a plain board adjoining the floor, called the plinth, and the upper of one or more mouldings, which, taken collectively, are called the base-mouldings. In better sort of work the plinth is tongued into a groove in the floor, by which means the diminution of breadth created by the shrinking never causes any aperture or chasm between its under edge and the floor, and the upper edge of the plinth is rebated upon the base. Bedrooms, lobbies, passages, and staircases are often finished without a dado and surbase, and indeed the fashion has extended the practice to rooms of the higher class, as drawing-rooms, &c.

BASEMENT. The lower story of a building, whether above or below the ground. See Book III. Chap. I. Sect. 13.

BASIL. Among carpenters and joiners the angle to which the edge of an iron tool is ground so as to bring it to a cutting edge. If the angle be very thin the tool will cut more freely, but the more obtuse it is the stronger and fitter it is for service.

BASILICA. (Gr. *βασιλευς*, a king.) Properly the palace of a king; but it afterwards came to signify an apartment usually provided in the houses of persons of importance, where assemblies were held for dispensing justice. Thus in the magnificent villa of the Gordian family on the Via Prenestina there were three basilicæ, each more than one hundred feet long. A basilica was generally attached to every forum, for the summary adjustment of the disputes that arose. It was surrounded in most cases with shops and other conveniences for traders. The difference between the Grecian and Roman basilica is given by Vitruvius in the fifth chapter of his first book. The rise and progress of the modern basilica is given, p. 109, *et seq.* The term basilica is also applied by Palladio to those buildings in the cities of Italy similar in use to our town halls.

BASIS. See BASE.

Basket. A term often applied to the vase of the Corinthian capital, with its foliage, &c.

Basse Cour. (Fr.) A court destined in a house of importance for the stables, coach-houses, and servants attached to that part of the establishment. In country houses it is often used to denote the yard appropriated to the cattle, fowls, &c.

Basso-relievo. See **Relievo.**

Bastard Stucco. See Sect. 9. Chap. III. Book II.

Bat. In bricklayer's work, a piece of a brick less than one half of its length.

Bath. (From the Saxon, Bað.) An apartment or series of apartments for bathing. Among the ancients the public baths were of amazing extent and magnificence, and contained a vast number of apartments. These extraordinary monuments of Roman magnificence seem to have had their origin in many respects from the gymnasia of the Greeks, both being instituted for the exercise and health of the public. The word *thermæ* (hot baths) was by the Romans used to denominate the establishment, although it contained in the same building both hot and cold baths. In later times a house was incomplete unless provided with hot and cold baths; and, indeed, it was not till the time of Augustus that public baths assumed the grandeur which their remains indicate. Different authors reckon nearly eight hundred baths in Rome, whereof the most celebrated were those of Agrippa, Antoninus, Caracalla, Diocletian, Domitian, Nero, and Titus. It appears from good authority, that the baths of Diocletian could accommodate no less than eight hundred bathers. These stupendous edifices are indicative of the magnificence, no less than the luxury of the age in which they were erected. The pavements were mosaic, the ceilings vaulted and richly decorated, and the walls encrusted with the rarest marbles. From these edifices many of the most valuable examples of Greek sculpture have been restored to the world; and it was from their recesses that the restorers of the art drew their knowledge, and that Rafaelle learnt to decorate the walls of the Vatican. See p. 96.

Baterdeau. (Fr.) The same as coffer dam, which see.

Batrachus. See **Architects**, list of, 33.

Batten. (Probably from the Fr. Bâton, from its small width.) A scantling or piece of stuff from two to six inches broad, and from five eighths of an inch to two inches thick. Battens are used in the boarding of floors and also upon walls, in order to receive the laths upon which the plaister is laid. See **Boarded Floor.**

Battening. The fixing of battens to walls for the reception of the laths on which the plaster is to be laid. It also signifies the battens in the state of being fixed for that purpose. The battens employed are usually about two inches broad and three fourths of an inch thick; the thicknesses, however, may be varied according to the distances that the several fixed points are from each other. Their distance in the clear is from eleven inches to one foot. Before battens are fixed, equidistant bond timbers should be built in the wall, or the wall should be plugged at equal distances, and cut off flush with its surface. In and about London plugs are generally placed at the distance of twelve or fourteen inches from centre to centre in the length of the batten. Battens upon external walls, the ceiling and bridging joists of a naked floor, also the common joists for supporting the boarding of a floor, are fixed at the same distance, viz. from eleven to twelve inches in the clear. When battens are fixed against flues, iron holdfasts are of course employed instead of bond-timbers or plugs. When they are attached to a wall they are generally fixed in vertical lines, and when fixed to the surface of a stone or brick vault, whose intrados is generated by a plane revolving about an axis, they ought to be placed in planes tending to the axis; as in this position they have only to be fixed in straight lines, in case the intrados is straight towards the axis, which will be the case when it is a portion of a cone or cylinder; and when the intrados is curved towards the axis they will bend the easiest possible. Great care should be taken to regulate the fans of the battens, so as to be as nearly as possible equidistant from the intended surface of the plaster. Though battens are employed in floors, neither the act of laying them nor the floor afterwards formed of them is called battening; they are more commonly called *boarding.* Every piece of masonry or brickwork, if not thoroughly dry, should be battened for lath and plaster, particularly if executed in a wet season. When windows are boarded, and the walls of the room not sufficiently thick to contain the shutters, the surface of the plastering is brought out so as to give the architrave a proper projection, and quarterings are used for supporting the lath and plaster in lieu of battens. This is also practised when the breast of a chimney projects into the room, in order to cover the recesses and make the whole side flush, or all in the same surface with the breast.

Batter (probably from the Fr. Battre). A term used by artificers to signify that a body does not stand upright, but inclines from a person standing before it; when, on the contrary, it leans towards a person, its inclination is described by saying it overhangs.

Battlements. Indentations on the top of a wall, parapet, or other building. They were first used in ancient fortifications, and subsequently applied to chambers and other buildings as mere ornaments. Their outline is generally a conjunction of straight lines at right angles to each other, each indentation having two interior right angles, and each raised part two exterior right angles.

Battle-embattled. A term applied to the top of a wall which has a double row of battlements formed by a conjunction of straight lines at right angles to each other, both embrasures and rising parts being double, the lower part of every embrasure less than the upper, and therefore the lower part of each riser broader than the upper.

Baulk Roofing. Roofing in which the framing is constructed of baulk timber.

Baulks. See Balks.

Bay. (Dutch, Baye.) The division of a barn or other building, generally from fifteen to twenty feet in length or breadth.

Bay. In plasterer's work, the space between the screeds prepared for regulating and working the floating rule. See Screeds.

Bay of Joists. The joisting between two binding joists, or between two girders when binding joists are not used.

Bay of Roofing. The small rafters and their supporting purlins between two principal rafters.

Bay Window. A window placed in the bay or bow of a window: called also an *oriel* window.

Bays. See Days.

Bazar. A species of mart or exchange for the sale of divers articles of merchandize. The word is Arabic, signifying the sale or exchange of goods or merchandise. Some of the Eastern bazars are open, like the market places of Europe, and serve for the same uses, more particularly for the sale of more bulky and less valuable commodities. Others are covered with lofty ceilings and even domes, which are pierced for the admission of light. It is in these that the jewellers, goldsmiths, and other dealers in rich wares have their shops. The bazar or *meidan* of Ispahan, one of the finest in Persia, is given in *fig.* 32.

Bead and Butt Work. Framing in which the pannels are flush, having beads *stuck* or run upon the two edges; the grain of the wood being in the direction of them. See p. 568.

Bead, Butt, and Square Work. Framing with bead and butt on one side, and square on the other, is chiefly used in doors. This sort of framing is put together square, and the bead is *stuck* on the edges of the rising side of the pannel.

Bead and Flush Work. A piece of framed work with beads run on each edge of the included pannel. See p. 568.

Bead, Flush, and Square Work. Framing with bead and flush on one side, and square on the other, used chiefly in doors.

Bead and Quirk. A bead stuck on the edge of a piece of stuff, flush with its surface, with only one quirk or without being returned on the other surface. *Bead and double quirk* occurs when the bead appears on the face and edge of a piece of stuff in the same manner, thus forming a *double quirk*.

Beade. (Sax. Beabe.) A moulding whose section is circular. It is frequently used on the edge of each fascia of an architrave, as also in the mouldings of doors, shutters, skirtings, imposts, and cornices. When the bead is flush with the surface it is called a *quirk-bead*, and when raised it is called a *cock-bead*.

Beak. A little pendent fillet left on the edge of the larmier, forming a canal behind to prevent the water from running down the lower bed of the cornice. The beak is sometimes formed by a groove or channel recessed on the soffite of the larmier upwards.

Beam (Sax. Beam, a tie.) A piece of timber, or sometimes of metal, for supporting a weight, or counteracting two opposite and equal forces, either drawing it or compressing it in the direction of its length. A beam employed as a lintel supports a weight; if employed as a tie beam, it is drawn or extended; if as collar beam, it is compressed. The word is usually employed with some other word used adjectively or in opposition, which word implies the use, situation, or form of the beam; as *tie beam*, *hammer beam*, *dragon beam*, *straining beam*, *camber beam*, *binding beam*, *girding beam*, *truss beam*, *summer beam*, &c. Some of these are however used simply, as collar for collar beam, lintel for lintel beam, &c. That which is now called the collar beam was by old writers called *wind beam*, and strut or *strutting beam*. A beam is lengthened either by building it in thicknesses, or by lapping or splicing the ends upon each other and bolting them through, which is called *scarfing*. See Carpentry generally, and p. 542.

Beam Compasses. An instrument for describing large circles, and made either of wood or metal with sliding sockets, carrying steel or pencil points. It is used only when the circle to be described is beyond the reach of common compasses.

Beam Filling. The brickwork or masonry brought up from the level of the under to the upper sides of the beams. It is also used to denote the filling up of the space from the top of the wall plate between the rafters to the under side of the slating, board, or other covering.

Bearer. That which supports any body in its place, as a wall, a post, a strut, &c. In gutters they are the short pieces of timber which support the boarding.

Bearing. The distance or length which the ends of a piece of timber lie upon or are inserted into the walls or piers; thus joists are usually carried into the walls at least nine inches, or are said to have a nine-inch bearing. Lintels of an aperture should in like manner have a similar bearing, the object being to prevent any *sagging* of the piece acting on the inner horizontal quoins of the wall.

Bearing of a Timber. The unsupported distance between its points of support without any intervening assistance. A piece of timber having any number of supports, one being placed at each extremity, will have as many bearings, wanting one, as there are supports. Thus a piece of timber extended lengthwise, as a joist over two rooms, will have three supports and two bearings, the bearers being the two outside walls and the partition in the midst between them.

Bearing Wall or Partition. A wall or partition built from the solid for the purpose of supporting another wall or partition, either in the same or in a transverse direction. When the latter is built in the same direction as the supporting wall it is said to have a *solid bearing;* but when built in a transverse direction, or unsupported throughout, its whole length is said to have a *false bearing*, or as many false bearings as there are intervals below the wall or partition.

Beater. An implement used by plasterers and bricklayers for beating, and thereby tempering or incorporating together the lime, sand, and other ingredients of a cement or plaster.

Beauchamp. See Architects, list of, 164.

Beaufet. See Buffet.

Beauty. In architectural composition, see Book III. Chap. I. Sect. 1.

Bed. (Sax. Beꝺ.) The horizontal surface on which the stones, bricks, or other matters in building lie. The under surface of a stone or brick is called its *under bed*, and the upper surface its *upper bed.* In general language the beds of a stone are the surfaces where the stones or bricks meet. It is almost needless to inculcate the necessity of every stone being worked quite straight, and not dished or hollowed out, which masons are very apt to do for the purpose of making a fine joint. Stones thus worked are very liable to flush and break off at the angles, of which there are too many examples in important buildings to make it necessary that we should more particularly allude to them. See Masonry, p. 518, *et seq.*

Bed Chamber. The apartment destined to the reception of a bed. Its finishings of course depend on the rank of the party who is to occupy it.

Bed of a Slate. The under side of a slate, or that part in contiguity with the boarding or rafters.

Beds of a Stone. In cylindrical vaulting are the two surfaces intersecting the intrados of the vault in lines parallel to the axis of the cylinder. In conic vaulting, where the axis is horizontal, they are those two surfaces which, if produced, would intersect the axis of the cone. In arching the beds are called *summerings* by the workmen.

Bedding of Timbers. The placing them properly in mortar on the walls.

Beech. One of the forest trees, but not often used in building. See p. 484.

Beetle. (Sax. Býꞇel.) A large wooden hammer or mallet with one, two, or three handles for as many persons. With it piles, stakes, wedges, &c., are driven.

Bek, de. See Architects, list of, 133.

Belection Mouldings. See Balection Mouldings.

Belfry. The upper part of the steeple of a church for the reception of the bells. It is the campanile of the Italians, though amongst them a building often altogether unconnected with the body of the church. It is sometimes used more especially in respect of the timber framing by which the bells are supported.

Bell of the Corinthian and Composite Capitals. The naked vase or *corbeille* round which the foliage and volutes are arranged. Its horizontal section is every where a circle. See *fig.* 93.

Bell Roof. One whereof the vertical section, perpendicular to the wall or to its springing line, is a curve of contrary flexure, being concave at the bottom and convex at the top. It is often called an ogee roof from its form.

Belt. In masonry, a course of stones projecting from the naked, either moulded, plain, fluted, or enriched with pateras at regular intervals.

Belvedere. (It.) A raised turret or lantern raised for the enjoyment of a prospect; also a small edifice in gardens, not uncommon in France and Italy.

Bench. A horizontal surface or table about two feet eight inches high, on which joiners prepare their work.

Bench Hook. A pin affixed to a bench for preventing the stuff in working from sliding out of its place.

Bergamasco. See Architects, list of, 192.

Bernini. See Architects, list of, 251.

Berruguette. See Architects, list of 223.

Berham. See Architects, list of, 107.

Beton. (Fr.) A species of concrete.

Bevel. (Lat. Bivium.) An instrument used by artificers, one leg whereof is frequently curved according to the sweep of an arch or vault. It is moveable upon a pivot or centre, so as to render it capable of being set to any angle. The make and use of it are much the same as those of the common square and mitre, except that those are fixed, the first at an angle of ninety degrees and the second at forty-five; whereas the bevel being moveable, it may in some measure supply the office of both, and yet supply the deficiency of both, which is, indeed, its principal use, inasmuch as it serves to set off or transfer angles either greater or less than ninety or forty-five.

Any angle that is not square is called a *bevel angle*, whether it be more obtuse or more acute than a right angle; but if it be one half as much as a right angle, viz. forty-five degrees, the workman calls it a *miter*. They have also a term *half miter*, which is an angle one quarter of a quadrant or square, that is, an angle of twenty-two degrees and a half.

Billet Moulding. (Fr. Billet.) A Norman moulding used in string courses and the archivolts of openings. It consists of short, small, cylindrical pieces, two or three inches long, placed in hollow mouldings at intervals equal to about the length of the billet. See p. 174.

Binding Joists. Those beams in a floor which, in a transverse direction, support the bridging joists above, and the ceiling joists below. (See Carpentry, p. 541.) When they are placed parallel to that side of a room on which the chimney stands, the extreme one on that side ought never to be placed close to the breast, but at a distance equal to the breadth of the slab, in order to allow for the throwing over the brick trimmer to support the hearth.

Binding Rafters. The same as purlins, which see.

Binns for Wine. The open subdivisions in a cellar for the reception of wine in bottles. The average diameter allowed for green bottles is 3·56 inches. Thus a binn 6 ft. 2¾ in. long will take twenty-one bottles. If they are laid in double tiers the depth should be 32 inches.

Birch. A forest tree (*Betula*) sometimes used in building, see p. 487.

Bird's Mouth. An interior angle cut on the end of a piece of timber, for the purpose of obtaining a firm rest upon the exterior angle of another piece.

Biscopius. See Architects, list of, 67.

Bit. An instrument for boring holes in wood or any other substance, so constructed as to admit of being inserted or taken out of a spring. The handle is divided into five parts, all in the same plane; the middle and the two extreme parts being parallel. The two extreme parts are in the same straight line, one of them having a brass end with a socket for containing the bit, which, when fixed, falls into the same straight line with the other end of the stock; the further end has a knob attached, so as to remain stationary, while all the other parts of the apparatus may be turned round by means of the projecting part of the handle.

There are various kinds of bits; as *shell bits*, used for boring wood, and having an interior cylindric concavity for containing the core; *centre bits* used to form a large cylindric hole or excavation; *countersink bits*, for widening the upper part of a hole in wood or iron, to take in the head of a screw or pin, so that it may not appear above the surface of the wood; *primer bits*, for widening holes; and *taper shell bits*, used also for the last named purpose.

Bitumen. A mineral pitch used in former ages instead of mortar. The walls of Babylon are said to have been cemented with it.

Blades. (Sax. Blæd.) A name sometimes given to the principal rafters of a roof.

Blade of a Chisel. The iron or steel part of it as distinguised from the wooden handle.

Blade of a Saw. The thin steel part on the edge of which the teeth are cut. The chief properties of a good saw are, that it should be stiff and yet bend equally into a regular curve, well tempered, equally thick on the cutting edge, and thinner towards the back edge.

Blank Door. A door either shut to prevent a passage, or one placed in the back of a recess, where there is no entrance, having, nevertheless, the appearance of a real door.

Blank Window. One which has the appearance of a real window but is merely formed in the recess of the wall. When it is necessary to introduce blank windows for the sake of uniformity, it is much better to build the apertures like the other and real windows, provided no flues or funnels interfere; and instead of representing the sashes by painting, real sashes should be introduced with the panes of glass painted on the back.

Blinds. Quadrangular frames of wood or metal, covered with an opaque substance, stretched between the framing, so as to cover either the whole or part of the sashes of a window. They are used for the purpose of diminishing the intense effects of the sun's rays, or of preventing passengers from seeing into the interior of an apartment.

Block (Teutonic) of Wood. A piece of wood cut into some prescribed form for a particular purpose.

Block of Stone or Marble. A piece rough from the quarry before it has received any form from the hand of the workman.

Blocking or Blocking Course. In masonry, a course of stones placed on the top of a cornice forming the crown of a wall.

Blockings. Small pieces of wood fitted in and glued to the interior angle of two boards, or other pieces, for the purpose of giving additional strength to the joint. In gluing up columns the staves are glued up successively and strengthened by blockings; as also the risers and treads of stairs and all other joints that demand more strength than their own joints afford. They are always concealed from the eye.

Blond, J. B. See Architects, list of, 274.

Blondel, Fr. See Architects, list of, 260.

Blondel, Jac. Fr. See Architects, list of, 293.

Board. (Sax. Boꞃꝺ.) A piece of timber of undefined length, more than four inches in breadth, and not more than two inches and a half in thickness. When boards are of a trapezoidal section, that is, thinner on one edge than the other, they are called *feather-edged boards*. Boards when wider than nine inches are called *planks*. The fir boards called *deal* (because they are *dealt* or *divided* out in thicknesses) are generally imported into England ready sawn, being thus prepared cheaper by saw mills abroad than they can be here. Fir boards of this sort, one inch and a quarter thick, are called *whole deal*, and those a full half inch thick, *slit deal*.

Board Lear or Lear Board. That upon which the lead work of a gutter is laid to prevent it sinking between the rafters.

Boards, Listed. Such as are reduced in their width by taking off the sap from the sides.

Boards for Valleys or Valley Boards. Those fixed on the valley rafters, or pieces for the leaden gutters of the valley to rest on.

Boarded Floors. Those covered with floors. The laying of floors usually commences when the windows are in and the plaster dry. The boards should be planed on their best face and set up to season, till the natural sap is expelled. They are then to be planed smooth, shot, and squared on the edge. The opposite edges are brought to a breadth by drawing, with a flooring guage, a line on the face parallel to the other edge. After this they are guaged to a thickness, and rebated down on the back to the lines drawn by the guage. The next thing is to try whether the joists be level, and if not, either the boards must be cut on the under side to meet the inequality, or the joists must be *furred* up by pieces to bring the boards, when laid, to a level. The boards employed in flooring are either battens or deals of greater breadth. The quality of battens is divided into three sorts. The best is that free from knots, shakes, sap wood, or cross-grained stuff, well matched and selected with the greatest care. The second best is that in which only small but sound knots are permitted, but it is to be free from sapwood and shakes. The most inferior kind is that left from the selection of the other two. See p. 574.

Boarding Joists. Those in naked floorings to which the boards are to be fixed.

Boarding for Lead Flats and Gutters. That which immediately receives the lead, rarely less than one inch and an eighth, or one inch and a quarter thick. It is usually laid merely with rough joints.

Boarding Luffer or Lever Boarding. Inclined boarding, with intervals between the boards, nailed in an inclined direction on the sides of buildings or lanterns, so as to admit a free current of air, and at the same time to exclude the rain.

Boarding for Pugging or Deafening, also called Sound Boarding. Short boards disposed transversely between the joists of floors to hold some substance intended to prevent sound being transmitted from one story to another. These boards are supported by *fillets* fixed to the sides of the joists about three quarters of an inch thick and an inch wide. The substance, often plaster, placed between them to prevent the transmission of the sound, is called the *pugging*.

Boarding for Slating. That nailed to the rafters for the reception of the slates, usually three quarters to seven eighths of an inch in thickness; the sides commonly rough, the edges either rough, shot, plowed and tongued, or rebated and sometimes *sprung*, so as to prevent the rain from passing through the joints. The boarding for slating may be so arranged as to diminish the lateral pressure or thrust against the walls by disposing the boards diagonally on the rafters. On the lower edge of the boarding is fixed the *eaves board*, as also against all walls either at right angles to or forming an acute angle with the ridge, or a right or obtuse angle with the wall plate. The eaves board is for raising the lower ends of the lower row of slates that form the eaves. Those placed against walls are for raising the slates to make the water run off from the wall. The boarding for slates should be of yellow deal without sap.

Boarding for lining Walls. The boards used for this purpose are usually from five eighths to three quarters of an inch thick, and are plowed and tongued together.

Boarding for outside Work, or Weather-boarding. Boards nailed with a lap on each other, to prevent the penetration of the rain and snow. The boards for this purpose are generally made thinner on one side than on the other, especially in good permanent work. The feather-edged board is, therefore, in such cases, used, the thick edge of the upper board being laid on the thin edge of that below, lapping about an inch or an inch and a half, and the nails being driven through the lap.

Boaster. A tool used by masons to make the surface of the work nearly smooth. It is two inches wide in the cutting part.

Boasting in Masonry. The act of paring the stone with a broad chisel and mallet, but not in uniform lines.

In CARVING, it is the rough cutting round the ornaments, to reduce them to their contours and profiles, before the incisions are made for forming the raffels or minuter parts. See Ashlar.

Body of a Niche. That part of it whose superficies is vertical. If the lower part be cylindrical and the upper part spherical, the lower part is the *body* of the niche, and the upper part is termed the *head*.

Body Range of a Groin. The wider of two vaults which intersect and form a groin.

Body of a Room. That which forms the main part of the apartment, independent of any recesses on the ends or sides.

Boffrand. See Architects, list of, 280.

Bolection Moulding. See Balection Moulding.

Bolster. The baluster part of the Ionic capital on the return side. See Baluster.

Bolt. (Gr. βολις, a dart). In joinery, a metal fastening for a door, and moved by the hand, catching in a staple or notch which receives it. Bolts are of various sorts, whereof *plate spring* and *flush bolts* are for fastening doors and windows.

This name is also given to large cylindrical iron or other metal pins, having a round head at one end and a slit at the other. Through the slit a *pin* or *forelock* is passed, whereby the bar of a door, window shutter, or the like is made fast. These are usually called round or window bolts.

The bolt of a lock is the iron part that enters into a staple or jamb when the key is turned to fasten the door. Of these the two sorts are, one which shuts of itself when the door is shut to, called a *spring bolt*; the other, which is only acted upon by applying the key, is called the *dormant bolt*.

In carpentry, a bolt is usually a square or cylindrical piece of iron, with a knob at one end and a screw at the other, passing through holes for its reception in two or more pieces of timber, for the purpose of fastening them together, by means of a nut screwed on the end opposite to the knob. The bolt of carpentry should be proportioned to the size and stress of the timbers it connects.

Boltel. See Boultine.

Bolton. See Architects, list of, 186.

Bond. (Sax.) Generally the method of connecting two or more bodies. Used in the plural number, it signifies the timbers disposed in the walls of a house, such as *bond timbers, lintels*, and *wall plates*. The term *chain bond* is sometimes applied to the bond timbers placed in one or more tiers in the walls of each story of a building, and serving not only to tie the walls together during their settlement, but afterwards for nailing the finishings to.

Bond. In masonry or brickwork is the disposition of stones or bricks, so that vertical joints may not fall over one another. See p. 519.

Bond (Heart). That bond which occurs when two stones being placed in a longitudinal position extending the exact thickness of the wall, another stone is put over the joints in the centre of the wall.

Bond Masonry. See Bound Masonry.

Bond Stones. Those whose longest horizontal direction is placed in the thickness of the work. See p. 520.

Boneing, or Boning. (Etym. doubtful.) The act of judging of or making a plane surface or line by the eye. It is also performed by joiners with two straight edges, by which it is seen whether the work is out of *winding*, that is, whether the surface be plane or twisted.

Bonomi. See Architects, list of, 308.

Booth. (British, Bwth.) A stall or standing in a fair or market. The term is also applied to any temporary structure for shade and shelter, as also for wooden buildings for itinerant players and pedlars.

Borders. (Fr. Bord.) Pieces of wood put round the upper edges of any thing, either for use or ornament. Such are the three pieces of wood, to which the term in architecture is more usually applied, which are mitred together round the slab of a chimney-piece.

Boring. The art of perforating any solid. For wood the various sorts of bits are described under Bit.

Borromini. See Architects, list of, 255.

Boss. (Fr.) In sculpture, a projecting mass or prominency of material, to be afterwards cut or carved.

Boss. Among bricklayers, a wooden vessel used by the labourers for the mortar used in tiling. It has an iron hook, by which it hangs on the laths or on the rounds of a ladder.

Bossage. (Fr.) Projecting stones laid rough in building to be afterward cut into mouldings or carved into ornaments. The term is also used to signify rustic work, which seems to advance before the naked of a building, by reason of indentures or channels left at the joints. The cavities or indentures at the joints are sometimes bevelled or chamfered, and sometimes circular.

Bouchardon. See Architects, list of, 284.

Boulder Walls. Such as are built of round flints or pebbles laid in strong mortar. This construction is used where there is a beach cast up by the sea, or where there is an abundance of flints in the neighbourhood.

Boultine or Boltel. A name sometimes given by workmen to a convex moulding, such as an ovolo.

Bound or Bond Masonry. That wherein the stones of each succeeding course are laid so that the joint which mounts and separates two stones always falls directly over the middle of the stone below.

Boutant. See Arc-boutant.

Bow. (Sax. Bugen). The part of any building which projects from a straight wall. It is sometimes circular and sometimes polygonal on the plan, or rather formed by two exterior obtuse angles. Bows on polygonal plans are called *canted bows.*

Bow. Among draughtsmen, denotes a beam of wood or brass, with three long screws that direct a lath of wood or steel to an arch. It is used in drawing flat arches of large radius.

Bow Compasses are instruments for describing small circles.

Bow Room. A room having a bow on one or more sides of it. See Bay Window.

Bow Saw. One for cutting the thin edges of wood into curves.

Bowlers or BoldERS. See Pavement.

Box. (Sax.) Generally, a case for holding any thing.

Box for Mitering. A trough for cutting miters. It has three sides, and is open at the ends, with cuts on the vertical sides at angles of forty-five degrees with them.

Box of a Rib-saw. Two thin iron plates fixed to a handle, in one of which plates an opening is made for the reception of a wedge, by which it is fixed to the saw.

Box of a Theatre. One of the subdivisions in the tiers round the circle.

Boxed Shutters. See Boxings of a Window.

Boxings of a Window. The cases opposite each other on each side of a window, into which the shutters are folded or fall back. The shutters of principal rooms are usually in two divisions or halves, each subdivided into others, so that they may be received within the boxings. The subdivisions are seldom more in number than three, and are so contrived that the subdivision whose face is visible, which is called the front shutter, is of the exact breadth of the boxing, and also flush with it; the next, hidden in the boxing, is somewhat less in breadth than that last mentioned, and the third still less. Suppose, for instance, a window four feet wide, standing in a two-brick or eighteen-inch wall; we may thus find the number of leaves each of the halves must have, as follows: — To the thickness of the wall add that of the plastering, say 2 inches, and we have 20 inches. Now the sash frame =6 inches in thickness, being added to the *reveal* or distance =4½ inches of the sash frame from the face of the wall =10½ inches, which, subtracted from 20, the thickness of the wall and plaster, leaves 9½ inches. This will give three leaves, or subdivisions, and as it is usual to make the *back flaps*, or those folded within the boxings, less than the front shutter, whose face is visible and flush with and of the exact breadth of the boxings, the arrangement may be as follows: — Front shutter 9½ inches, the next 8 inches, and the third 6½ inches; in all, 24 inches, the half of the opening of the window. It will be perceived that no allowance has been made for the shutters being rebated into each other, as is usually the case; and for this half an inch more must be allowed for the two rebates of the three leaves, and one eighth of an inch for the rebate at the meeting of the two principal divisions in the middle of the window, making, with the breadth of the three subdivisions, 24 + ⅝: the flaps, therefore, may be thus disposed: — Front leaf 9⅝ inches, second leaf $8\frac{1}{4}$ inches, and the third leaf $6\frac{3}{8}$ inches; in all $24\frac{5}{8}$ inches, being fully the width of each principal division. To find the depth to be given to the boxings, to the thickness of each of the leaves add one sixteenth of an inch, and if there be a back lining add also the thickness of that. The second and third flaps are almost always thinner than the front leaf; thus, say front leaf $1\frac{1}{2}$ inch, second leaf $1\frac{1}{4}$ inch, and third leaf $1\frac{1}{4}$ inch; to which add $\frac{3}{16}$ for the three leaves, and the amount will stand thus:— $1\frac{1}{2}+1\frac{1}{4}+1\frac{1}{4}+\frac{3}{16}=4\frac{3}{16}$ inches for the depth of the boxings. If the walls are only a brick and a half thick, or the window very wide, the architrave is made to project below the face of the plaster, for the purpose of obtaining width for the boxings, or the plaster is brought out from the internal face of the wall by means of battening.

Boyden. See Architects, list of, 132.

Brace. (Fr. Embrasser.) An inclined piece of timber used in trussed partitions and in framed roofs, in order to form a triangle, by which the assemblage of pieces composing the framing are stiffened. When a brace is used to support a rafter, it is called a *strut*. When braces are used in roofs and in partitions, they should be disposed in pairs, and introduced in opposite directions. See Angle Brace.

Bracket. (Lat. Brachium.) A supporting piece for a shelf. When the shelf is broad the brackets are small trusses, which consist of a vertical piece, an horizontal piece, and a strut; but when narrow the brackets are generally solid pieces of board, usually finished with an ogee figure on their outer side.

Brackets for Stairs are sometimes used under the ends of wooden steps next to the well-hole, for the sake of ornament only, for they have only the appearance of supports.

Bracketing for Cornices. The wooden ribs nailed to the ceiling, joists, and battening for supporting the cornices of rooms when too large for security, by the mere dependence on the adhesive power of plaster to the ceiling. It consists of vertical ribs whose rough outline is that of the cornice, and to which the laths are nailed for sustaining the plaster in which the mouldings are run. The bracketing for coves is only an enlargement of the scale which occurs in ordinary cornices, the operation being that of obtaining a set of ribs to which the laths may be nailed for the reception of the plastering. The ribs in question are usually out of deals, whose thickness must necessarily vary with the weight of plaster they have to support. See p. 558, *et seq.*

Brad. (Etym. uncertain.) A thin nail used in joinery without the spreading head which other nails have, the projection of the head being only on one side. There are various sorts of brads, such as *joiners' brads* for hard woods; others, called *batten brads*, for softer woods; and *bill*, or *quarter brads*, used for a hastily laid floor. When brads are used they are generally driven below the surface of the wood through the medium of a *punch*, and the hole is filled up with putty to prevent an appearance of the nailing.

Bramante. See Architects, list of, 167.

Bramantino. See Architects, list of, 156.

Branches. The ribs of a Gothic vault, rising upwards from the tops of the pillars to the apex. They appear to support the ceiling or vault.

Brandrith. A fence or rail round the opening of a well.

Brass. A metal much used in building. It is an alloy of copper and zinc, whose proportions vary according to the required colour. Four parts of copper and one of zinc form a good brass. The common process for making it is by heating copper plates in a mixture of native oxide of zinc, or calamine and charcoal.

Brasses. Sepulchral plates, generally sunk into a flat grave-stone; sometimes with a mere inscription, but very frequently with effigies, armorial bearings, and other devices engraved upon it.

Brattishing. Interpreted, we know not how truly, as the carved open work over a shrine.

Bray. See Architects, list of, 176.

Breadth. The greatest extension of a body at right angles to its length.

Break. The recess or projection of any part within or beyond the general face of the work. In either case it is to be considered a break.

Break in. In carpentry, is the cutting or breaking a hole in brickwork with the ripping-chisel for the purpose of inserting timber, or to receive plugs, the end of a beam, or the like, &c.

Breaking Joint. In masonry or brickwork, is the placing a stone or brick over the course below, in such a manner that the joint above shall not fall vertically immediately above those below it.

Breast of a Chimney. The projecting or facing portion of a chimney front towards a room which projects into it, or which, from other construction, may not have a break. It is, in fact, the wall carried up over the front of a fireplace, whether projecting or not. See Chimney.

Breast of a Window. The masonry or brickwork forming the back of the recess or parapet under the window sill.

Breeze. Small ashes and cinders used instead of coal for the burning of bricks.

Bressummer or Breast Summer. That is, a summer or beam placed breastwise for the support of a superincumbent wall, performing in fact the office of a lintel. It is principally used over shop windows to carry the upper part of the front, and supported by iron or timber posts, though sometimes by stone. In the interior of a building the pieces into which the girders are framed are often called summers.

Brettingham. See Architects, list of, 294.

Brewhouse. An establishment for the manufactory of malt liquors. A brewhouse is generally provided as an appendage to dwelling-houses in the country, for brewing the beer used by the family.

Brick. (Dutch, Bricke.) A sort of fictitious stone, composed of an argillaceous earth, tempered and formed in moulds, dried in the sun, and finally burnt to a proper degree of hardness in a clamp or kiln. (See Book II. Chap. II. Sect. 9.) The method pursued by the ancients in making unburnt bricks is described by Vitruvius, book ii. chap. iii. After mentioning the process, that author thus describes the different sorts in use: — "There are three sorts of bricks; the first is that which the Greeks call Didoron (διδῶρον), being the sort we use, that is, one foot long and half a foot wide. The other two sorts are used in Grecian buildings; one is called Pentadoron, the other Tetradoron. By the word Doron, the Greeks mean a palm, because the word δῶρον signifies a gift which can be borne in the palm of the hand. That sort, therefore, which is five palms each way is called Pentadoron; that of four palms Tetradoron. The former of these two sorts is used in public buildings; the latter in private. Each sort has half bricks made to suit it; so that when a wall is executed, the course on one of the faces of the wall shows sides of whole bricks, the other face of half bricks; and being worked to the line on each face, the bricks on each bed bind alternately over the course below. Besides the pleasant varied appearance which this method gives, it affords additional strength by the middle of a brick on a rising course falling over the vertical joints of the course thereunder." Towards the decline of the Republic, the Romans made great use of bricks as a building material. According to Pliny, those most in use were a foot and a half long, and a foot broad. This agrees nearly with the Roman bricks used in England, which are generally found to be about seventeen inches in length by eleven inches in breadth. Ancient bricks are generally very thin, being often no more than one inch and a half thick. From the article by Quatremère de Quincy in the *Encyc. Méthodique*, it appears from his researches among the antique buildings of Rome, he found bricks of the following sizes. The least were 7½ inches (French) square and 1½ inch thick; the medium one 16½ inches square, and from 18 to 20 lines in thickness. The larger ones were 22 inches square by 21 or 20 lines thick. The smaller ones were used to face walls of rubble work; and, for making better bond with the wall, they were cut diagonally into two triangles, the longer side being placed on the outside, and the point towards the interior of the work. To make the tie more effectual between the rubble and the facing, they placed at intervals of 4 feet in height, one or two courses of large square bricks. The larger bricks were also used for the arches of openings to discharge the superincumbent weight.

Bricklayers' Work or Bricklaying. See Book II. Chap. III. Sect. 2.

Brickwork. Any work performed with bricks as the solid material.

Bridge. (Sax. Bꞃɪᵹᵹe.) A structure for the purpose of connecting the opposite banks of a river, gorge, valley, &c., by means of certain materials, forming a road-way from one side to the other. It may be made of stone, brick, iron, timber, suspended chains or ropes, or the road-way may be obtained by means of boats moored in the stream. On the general principles for the situation and construction, the reader is referred to Book III. Chap. III. Sect. 2.; and for the principles and mode of constructing arches, to Book II. Chap. I. Sect. 9.

Bridge Board, otherwise called **Notch Board,** is a board on which the ends of the steps of wooden stairs are fastened.

Bridge-over. A term used when several parallel timbers occur, and another piece is fixed transversely over them, such piece is then said to *bridge-over* the parallel pieces. Thus in framed roofing, the common rafters bridge-over the purlins; so, in framed flooring, the upper joists, to which the flooring is fixed, bridge-over the beams or binding-joists, and for this reason they are called *bridging-joists.*

Bridge Stone. A stone laid from the pavement to the entrance door of a house, over a sunk area, and supported by an arch.

Bridged Gutters are those made with boards supported by bearers, and covered above with lead.

Bridging Floors are those in which bridging-joists are employed. See p. 541.

Bridging Joists. Those which are sustained by transverse beams below, called *binding joists;* also those joists which are nailed or fixed to the flooring-boards.

Bridgings or Bridging Pieces, also called **Strutting or Straining Pieces,** are pieces placed between two opposite beams to prevent their nearer approach, as rafters, braces, struts, &c. When a strutting-piece also serves as a sill, it is called a *straining sill.*

Bringing-up or Carrying-up. A term used by workmen to denote building up. Thus, *bringing-up* a wall four feet means building it up.

Briosco. See Architects, list of, 202.

Broached Work. See Droved and Broached.

Broad Stone. The same as free-stone.

Bronteum. (Gr.) In ancient Greek Architecture, that part of the theatre under the floor in which brazen vessels with stones in them were placed to imitate the sound of thunder.

Bronze. A compound metal applied to various useful and ornamental purposes. The composition consists of 6 to 12 parts of tin and 100 parts of copper. This alloy is heavier and more tenacious than copper; it is also much more fusible, and less liable to be altered by exposure to the air.

Brosse, Jacques de. See Architects, list of, 248.

Brunelleschi. See Architects, list of, 147.

Budget. A small pocket used by tilers for holding the nails in lathing for tiling.

Buffet. (Fr.) A cabinet or cupboard for plate, glass, or china. Some years back it was the practice to make these small recesses very ornamental, in the form of niches, and left open in the front to display the contents. At present, when used, they are generally closed with a door.

Builder. A person who contracts for performing the whole of the different artificers' works in a building.

Building. Used as a substantive is the mass of materials shaped into an edifice. As a participle, it is the constructing and raising an edifice suited to the purposes for which it is erected; the knowledge requisite for the design and construction of buildings being the subject of this work, in which it is treated under its various heads.

Building Act. An act passed 14 Geo. 3. cap. 78. for regulating buildings within the bills of mortality of London. See p. 819.

Building of Beams. The same as Scarfing. See p. 542.

Bulker. A term used in Lincolnshire to signify a beam or rafter.

Bull's Eye. Any small circular aperture for the admission of light or air.

Bull's Nose. The external or other angle of a polygon, or of any two lines meeting at an obtuse angle.

Bullen Nails. Such as have round heads with short shanks turned and lacquered. They are principally used in the hangings of rooms.

Bullock Sheds. Houses or sheds for feeding bullocks, in which the main points to be observed are good ventilation, facility in feeding and cleaning the animals, perfect drainage, and a good aspect. They ought not to be less than nineteen feet wide.

Bundle Pillar. In Gothic architecture, a column consisting of a number of small pillars round its circumference.

Buonarrotti, M. A. See Architects, list of, 219.

Buono. See Architects, list of, 95.

Buono, Bartolomeo. See Architects, list of, 191.

Buontalenti. See Architects, list of, 241.*

Burlington, Earl of. See Architects, list of, 293.

Burroughs. See Architects, list of, 287.

Buschetto. See Architects, list of, 18.

Butamente. See Architects, list of, 233.

But-hinges. Those employed in the hanging of doors, shutters, casements, &c. They are placed on the edges with the knuckle projecting on the side in which the *closure* is to open, and the other edges stopping against a small piece of wood left in the thickness of the closure so as to keep the arris entire. Workmen generally sink the thickness of the hinges flush with the surface of the edge of the closure, and the *tail part* one half into the jamb. Of but-hinges there are several kinds; such as *stop but-hinges*, which permit the closure to open only to a right angle, or perhaps a little more, without breaking the hinges; *rising but-hinges*, which are those that turn upon a screw; these are most employed in doors, and cause the door to rise as it opens, so as to clear the carpet in the apartment; *slip-off but-hinges*, which are those employed where a door or window blind is required to be taken off occasionally.

Butment. The same as Abutment, which see.

Butment Cheeks. The two solid sides of a mortise. The thickness of each cheek is usually equal to the thickness of the mortise, but it happens that circumstances arise to vary this thickness.

Butt-end of a Piece of Timber. That which was nearest the root of a tree.

Buttery. A store-room for provisions, which, if possible, should be on the north side of a building.

Butting Joint. That formed by the surfaces of two pieces of wood, whereof one is perpendicular to the fibres, and the other in their direction, or making an oblique angle with them, as for example, the joints made by the struts and braces with the truss posts.

Button. A small piece of wood or metal, made to turn about a centre for fastening a door, draw, or any other kind of closure. The centre is generally a nail, which should be smooth, rounded, and the head filed even.

Buttress. (Fr. Aboutir, to lie out.) A mass of brickwork or masonry to support the side of a wall of great height, or pressed on the opposite side by a bank of earth or body of water. Buttresses are employed against the piers of Gothic buildings to resist the thrust of the vaulting. See Arc Boutant, or flying buttress. The buttress called the pillared buttress is formed by vertical planes attached to the walls themselves. These sometimes form the upright terminations of flying buttresses.

C.

Cabin. (Brit. Chabin.) A term applied to the huts and cottages of poor people and to those of persons in a savage state of life.

Cabinet. (Fr.) A retired room in an edifice set apart for writing, study, or the preservation of any thing curious or valuable. The term is also applied to an apartment at the end of a gallery in which pictures are hung, or small pieces of sculpture, medals, bronzes, and other curiosities are arranged.

Cable. A moulding of a convex circular section, rising from the back or concave surface of a flute, so that its most prominent part may be in the same continued circular surface as the fillet on each side of the flute. Thus the surface of a flute is that of a concave cylinder, and that of the cable is the surface of a convex cylinder, with the axes of the cylinders parallel to each other. The cable seems to represent a rope or staff laid in the flute, at the lower part of which it is placed about one third of the way up.

Cabled Column. One in which cables, as described in the last article, are used.

Cabled Flutes. Such as are filled with cables.

Cabling. The filling of the flutes with cables, or the cables themselves so disposed. Cabling of flutes was not frequently used in the works of antiquity. The flutes of the columns of the arch of Constantine are filled with cables to about one third of the height of the shaft. Most of the columns in the ruins of Baalbec, Palmyra, and the palace of Diocletian at Spalatro, have neither flutes nor cables. In modern times an occasional abuse has been practised of cabling without fluting, as in the church della Sapienza at Rome.

Caer. A term in British antiquity, which, like the Saxon term *Chester*, denotes a castle, and is generally prefixed to the names of places fortified by the Romans.

Cage, in carpentry, is an outer work of timber inclosing another within it. Thus the cage of a stair is the wooden inclosure that encircles it.

Caisson. (Fr.) A large and strong chest of timber, water-tight, used in large and rapid rivers for building the pier of a bridge. The bottom consists of a grating of timber, contrived in such a manner that the sides, when necessary, may be detached from it. The ground under the intended pier is first levelled, and the caisson being launched and floated into its proper position, it is sunk, and the pier built therein as high as the level of the water, or nearly so. The sides are then detached, and the pier, built as described, sinks down on the foundation prepared for it. The tonnage of each of the caissons used at Westminster Bridge was equal to that of a forty-gun ship.

Caissons in Vaulting. The sunken pannels on ceilings, vaults, and cupolas. See Book III. Chap. II. Sect. 3.

Calcareous Cements. See Cement in the body of the work, p. 505, *et seq.*

Calcareous Earth. A species of earth which becomes friable by burning, and is afterwards reduced to an impalpable powder by mixing it with water. It also effervesces with acids. It is frequently met with in a friable or compact state in the form of chalk.

Caldarium. (Lat.) In ancient architecture a close vaulted room, in which persons were brought into a state of profuse perspiration. It was one of the apartments attached to ancient baths, and was also denominated *Vaporarium*, *Sudatorium*, and *Laconicum*.

Calfpen. A place for nourishing calves. It is generally a small apartment within the cowhouse; but the practice is not to be recommended, as it keeps the cow in a restless and agitated state, and prevents her from feeding well, and giving that quantity of milk she would otherwise furnish.

Caliber. (Etym. uncertain.) The greatest extent or diameter of a round body.

Caliber Compasses. Those made with bent legs for taking the diameter of a convex or concave body in any part. See Mould.

Caliducts. (Lat.) Pipes or channels disposed along the walls of houses and apartments. They were used by the ancients to convey heat to the remote parts of the house from one common furnace.

Caliper. See Caliber.

Callias. See Architects, list of, 18.

Callicrates. See Architects, list of, 13.

Callimachus. See Architects, list of, 24.

Calotte. (Fr.) A concavity in the form of a cup or niche, lathed and plastered, serving to diminish the height of a chapel, alcove, or cabinet, which otherwise would appear too high for the breadth.

Camaroris. (Gr.) An elevation terminated with an arched or vaulted head.

Camber. (Gr.) An arch on the top of an aperture or on the top of a beam. Hence camber windows.

Camber Beams. Those which form a curved line on each side from the middle of their length. All beams should, to some degree, if possible, be cambered; but the cambered beam is used in flats and church platforms, wherein, after being covered with boards, these are covered with lead, for the purpose of discharging the rain-water.

Camerated. (Gr.) The same as arched.

Cames. Small slender rods of cast lead in glazing, twelve or fourteen inches long, of which, by drawing them separately through a species of vice, the glaziers make their turned lead for receiving the glass of casements.

Camp Ceiling. A ceiling whose form is convex inwardly.

Campanile. (It. a bell tower.) A tower for the reception of bells, usually, in Italy, separated from the church. Many of the campaniles of Italy are lofty and magnificent structures. That at Cremona is much celebrated, being 395 feet high. It consists of a square tower, rising 262 feet, surmounted by two octagonal open stories, ornamented with columns; a conical shaft and cross terminate the elevation. The campanile of Florence, from the designs of Giotto, though in bad taste, has claims on our admiration for its richness and the superiority of the workmanship. It is 267 feet high, and 45 feet square. The most remarkable of the campaniles in the country mentioned is that at Pisa, commonly called the "Leaning Tower." It is cylindrical in general form, and surrounded by eight stories of columns, placed over one another, each having its entablature. Each column carries the springing of two arches, and there is an open gallery between the columns and the circular wall of the tower. The height of the last story of columns, in which are the bells, is set back from the general line of the elevation. The height is about 150 feet to the platform, whence a plumb line lowered falls on the leaning side nearly 13 feet beyond the base of the building.

Campbell. See Architects, list of, 271.

Campero. See Architects, list of, 198.

Camp-sheeting or Campshot. The sill or cap of a wharf wall.

Canal. (It. Canale.) A duct for the conveyance of a fluid; thus the canal of an aqueduct is the part through which the water flows. In ancient aqueducts it was lined with a coat of mastic.

Canal. A term sometimes used for the flutings of a column or pilaster. The *canal of the volute* is the spiral channel, or sinking on its face, commencing at the eye, and following in the revolutions of the volute. The *canal of the larmier* is the channel or groove sunk on its soffite to throw off the rain, and prevent it from running down the bed mould of the cornice.

Cancelli. (Lat.) Latticed windows, or those made with cross bars of wood or iron. The balusters or rails which close in the bar of a court of justice, and those round the altar of a church, are also so called; hence the word chancel.

Candelabrum. (Lat. Candela.) A stand or support on which the ancients placed a lamp. Candelabra varied in form, and were highly decorated with the stems and leaves of plants, parts of animals, flowers, and the like. The etymology of the word would seem to assimilate the candelabrum to our candlestick; it is, however, certain that the word *candela* was but a lamp, whereof the candelabrum was the support. In the works of Piranesi some of the finest specimens are to be found. The most curious, however, as respects form, use, and workmanship, are those excavated at Herculaneum and Pompeii. They are all of bronze, slender in their proportions, and perfectly portable, as they rarely in height exceed five feet. On none of the candelabra hitherto found is there any appearance of a socket or pipe at top, from which an inference as to the use of candles could be made.

Canephoræ. (Gr. *Κανηφορος*, bearing a basket.) Figures of young persons, of either sex, bearing on their heads baskets containing materials for sacrifice. They are frequently confounded with caryatides, from their resemblance in point of attitude and the modern abuse of their application.

Canopy. (Gr. *Κανοπειον*.) An ornamented covering over a seat of state; and in its extended signification any covering which affords protection from above. It is also the label or projecting roof that surrounds the arches and heads of gothic niches.

Cant. An external angle or quoin of a building. Among carpenters it is used as a verb, to signify the turning of a piece of timber which has been brought in the wrong way for their work.

Cant Moulding. One with one or more bevelled, instead of curved, surfaces. The cant moulding was used at an early period of the art.

Cantalever or Cantilever. (Probably from Canterii labrum, *the lip of the rafter.*) Blocks inserted into the wall of a building for supporting a balcony, the upper members of a cornice, or the eaves of a house, and the like. They answer the same purpose as modillions, mutules, blocks, brackets, &c., although not so regularly applied. They are, in modern use, not unfrequently made of timber or cast iron, and project considerably, as in the church of St. Paul, Covent Garden, which projects one quarter of the height of the column.

Canted Column. One whose horizontal sections are polygons. In the works of the ancients it is rarely met with. The examples immediately occurring to us are the columns of the portico of Philip of Macedon and of the temple of Cora.

Cantharus. A fountain or basin of water in the centre of the atrium before the ancient churches, wherein persons washed their faces and hands before they entered. Among the Romans the cantharus of a fountain was the part out of which the water issued.

Canthers or Canterii. In ancient carpentry the common rafters of a roof, whose ends, say some, the mutules of the Doric order represent.

Canting. The cutting away of a part of an angular body at one of its angles, so that its horizontal section becomes thereby the portion of a polygon of a greater number of sides whose edges are parallel from the intersection of the adjoining planes.

Cantoned Building. One whose angles are decorated with columns, pilasters, rustic quoins, or any thing projecting beyond the naked of the wall.

Cap. A term used in joinery, signifying the uppermost of an assemblage of parts. It is also applied to the capital of a column, the cornice of a door, the capping or uppermost member of the surbase of a room, the handrail of a staircase, &c.

Capital. (Lat. Caput.) The head or uppermost member of any part of a building; but generally applied in a restricted sense to that of a column or pilaster of the several orders, to which (Sections 3, 4, 5, 6, 7. Chap. I. Book III.) the reader is referred for the differences of their capitals. The chief of the capitals of Eastern and Egyptian architecture are shown in *figs.* 58, 59, &c.

Capital, angular. The modern Ionic capital, whose four sides are alike, showing the volute placed at an angle of 135° on all the faces.

Capital of a Baluster. The crowning or head mouldings of it.

Capital of a Lantern. The covering by which it is terminated; it may be of a bell form, that of a dome, spire, or other regular figure.

Capital of a Triglyph. The square band which projects over it. In the Roman Doric it has a greater projection than in the Grecian.

Capreoli. (Lat.) In ancient carpentry the joints or braces of a trussed roof. See *figs.* 91, 92.

Caracol. A term sometimes applied to a staircase in the form of a helix or spiral.

Caravansera. Among the Eastern nations a large public building or inn appropriated to the reception and lodgment of travellers by caravans in the desert. Though the caravansera serves the purpose of an inn, there is this essential difference between the two, that in the former the traveller finds nothing either for the use of himself or his cattle, but must carry all his provisions and necessaries with him. Caravanseras are also numerous in cities (see an example, *fig.* 33.), where they serve, not only as inns, but as shops, warehouses, and even exchanges.

Carcass. The naked building of a house before it is lathed and plaistered, or the floors laid, &c.

Carcass Flooring. That which supports the boarding, or floor boards, above, and the ceiling below, being a grated frame of timber, varying in many particulars which are described, Book II. Chap. III. Sect. 4., in the body of the work.

Carcass Roofing. The grated frame of timber work which spans the building, and carries the boarding and other covering. The method of framing the carcass roofing of a building in its varieties is given, p. 544, *et seq.*

Cardinal Scapi. In ancient Roman joinery, the stiles of doors.

Carilepho. See Architects, list of, 83.

Carolitic Column. One with a foliated shaft.

Carpenter. (Fr. Charpentier.) An artificer who cuts, forms, and shapes timbers for the purposes of giving strength and support to the various parts which are of timber, in the construction of buildings.

Carpenter's Rule. The rule by which carpenters take their dimensions, and also through the aid of a brass slide, which makes it a sliding rule, are enabled to make calculations in multiplication and division, besides other operations.

Carpenter's Square. An instrument whose stock and blade consists of an iron plate of one piece. One leg is eighteen inches long, and numbered on the outer edge from the exterior angle with the lower part of the figures adjacent to the interior edge. The other leg is twelve inches long, and numbered from the extremity towards the angle; the figures being read from the internal angle, as on the other side. Each of the legs is about an inch broad. This instrument is not only used as a square, but also as a level and measuring rule.

Carpentry. (Lat. Carpentum, carved wood.) An assemblage of pieces of timber connected by framing, or letting them into each other, as are the pieces of a roof, floor, centre, &c. It is distinguished from joinery by being put together, without the use of any other edge tools than the axe, adze, saw, and chisel, whereas joinery requires the use of the plane. The leading points that require attention in sound carpentry are,— 1. the quality of the timber used; 2. the disposition of the pieces of timber, so that each may be in such direction, with reference to the fibres of the wood, as to be most capable of performing its office properly; 3. the forms and dimensions of the pieces; 4th. the manner of framing the pieces into each other, or otherwise uniting them by means of iron, or other metal. The subject of carpentry in the body of the work is treated under the head of Mechanical Carpentry, Book II. Chap. I. Sect. 11., and of Practical Carpentry, in the same Book, Chap. III. Sect. 4.

Carrara Marble. The name of a species of white marble obtained at the quarries near the town bearing that name, in the Tuscan States. It was called *marmor lunense* and *ligustrum* by the ancients, and differs from the *Parian* marble by being harder in texture, and less bright in colour.

Carriage. The timber framework on which the styes of a wooden staircase are supported. See p. 443.

Carry up. See Bring up.

Cartouch. (Fr.) A name given to the modillion of a cornice used internally. It is also used to denote a scroll of paper, usually in the form of a tablet, for the reception of an inscription. In Egyptian architecture, applied to those parts of an hieroglyphic inscription enclosed by lines.

Carver. (Ceoꞃꝼan.) An artificer who cuts wood into various forms and devices. *Carving*, generally, is the art of cutting a body by recession, in order to produce the representation of an object, either in relief, or recessed within the general surface. In this sense it equally applies to the making of intaglios as to that of making cameos.

Caryatides. Figures used instead of columns for the support of an entablature. See Book I. Chap. II. Sect. 11., and Book III. Chap. I. Sect. 15.

Case. The outside covering of any thing, or that in which it may be enclosed. It is also a term used to denote the carcass of a house.

Case Bays. The joists framed between a pair of girders in naked flooring. When the flooring joists are framed with one of their ends let into a girder, and the opposite ends let into a wall, they are called *tail-bays*. The extent of the case-bays should not exceed ten feet.

Case of a Door. The wooden frame in which a door is hung.

Case of a Stair. The wall surrounding a staircase.

Cased. A term signifying that the outside of a building is faced or covered with materials of a better quality. Thus, a brick wall is said to be cased with stone, or with a brick superior in quality to that used in the inner part of the wall.

Cased Sash Frames. Those which have their interior vertical sides hollow, to admit the weights which balance the sashes hung between them.

Casemate. A hollow moulding, such as the *cavetto*, which see.

Casement. A glazed frame or sash, opening on hinges affixed to the vertical sides of the frame into which it is fitted.

Casing. See Lining.

Casino. (It. a small house.) A term applied now to a small country house; but formerly to one capable of affording defence on a small scale against an attacking force.

Castella. In ancient Roman architecture, reservoirs in which the waters of an aqueduct were collected, and whence the water was conducted through leaden pipes to the several parts of a city.

Castellated Houses. Those with battlements and turrets, in imitation of ancient castles.

Casting. In carpentry and joinery a term synonymous with warping. It means the bending of the surfaces of a piece of wood from their original state, caused either by the gravity of the material, by its being subject to unequal temperature, moisture, or the ununiform texture of the material.

Castle. (Lat. Castellum, or Sax. Caꞅꞇel.) A building fortified for military defence; also a house with towers, usually encompassed with walls and moats, and having a donjon or keep in the centre. The principal castles of England at present are those of the Tower of London, of Dover, Windsor, Norwich, &c. At one time those of Harwood, Spofforth, Kenilworth, Warwick, Arundel, and others, might have vied with these in importance. The characteristics of a castle are its *valla* (embankments) and *fossæ* (ditches); from the former whereof the walls rise usually crowned with battlements, and flanked by circular or polygonal bastions at the angles formed by the walls. These were pierced for gates, with fixed or drawbridges, and towers on each side. The gates of considerable strength were further guarded by descending gratings, called *portcullises*. All the apertures were made as small as they could be, consistent with internal lighting.

The component parts of the castle were — the *fosse* or *moat*, with its bridge; the *barbacan*, which was in advance of the castle, being a raised mound or tower, whose outer walls had terraces towards the castle, with their *bastions*, as above-mentioned; the *gatehouse*, flanked by towers, and crowned with projections called *machicolations*, through which heavy materials, or molten lead, were dropped on the assailants entering the gateway; the *outer ballium*, or *bailey*, or area within the castle, which was separated from the inner ballium by an embattled wall with a gatehouse, and in which the stables and other offices were usually seated; and the *inner ballium*, for the residence of the owner or governor, and his retinue; this, at one corner, or in the centre, had a *donjon*, or *keep tower*, which was the stronghold of the place, and contained a state apartment, a well, and a chapel; the former usually, and the latter frequently, are found in ancient castles. The reader who desires detailed information on this matter is referred to King's *Mun. Antiq.* 4 vols. folio; the Archæologia, in many places; Leland's *Collect.* vol. ii. &c. &c.

Catabasion. (Gr. Καταβαινω.) A place in the Greek church, under the altar, in which relics are deposited.

Catacombs. (Gr. Κατα, against, and Κομβος, a hollow place.) Subterraneous places for burying the dead. The hypogæa, crypta, and cimeteria of the ancients were used for the same purpose. In some cities the excavations for catacombs were of vast extent, and were used for other purposes than those of sepulture; at Syracuse, for instance, the same cavern served for a prison as well as a public cemetery. It has been said, that in the early ages of Christianity they served as places of public worship or devotion. The most celebrated for their extent are those of Rome, Naples, Syracuse, &c.; and the more modern ones of Paris, which have been formed by quarrying for the stone, whereof a great part of the city has been built.

Catafalco. (It. a scaffold.) A temporary structure of carpentry, decorated with painting and sculpture, representing a tomb or cenotaph, and used in funeral ceremonies. That used at the final interment of Michel Angelo, at Florence, was of a very magnificent description; and, for the art employed on it, perhaps unequalled by any other before or since its employment.

Catch Drain. A drain used on the side of a larger open one, or of a canal, to receive the surplus water of the principal conduit.

Catenary Curve. The mechanical curve formed by a heavy flexible cord or chain of uniform density, hanging freely from the two extremities. Galileo first noticed it, and proposed it as the proper figure for an arch of equilibrium. He, however, imagined that it was the same as the parabola. It was James Bernouilli who first investigated its nature, and its properties were thereafter pointed out by John Bernouilli, Huygens, and Leibnitz. From the first of these mathematicians, the following geometrical method of determining the relations between the parts of a catenary is translated. The catenarean curve is of two kinds, the *common*, which is formed by a chain equally thick or equally heavy in all its points; or *uncommon*, which is formed by a thread unequally thick, that is, which in all its points is unequally heavy, and in some ratio of the ordinates of a given curve. To draw the common catenary mechanically, suspend on a vertical plane a chain of similar and equal links of homogeneous matters, as flexible as possible, from any two points not in a perpendicular line, nor so distant from each other as the length of the chain. Prick the plane through the links as nearly as possible in the middle of the chain, and through the points draw the catenary (*fig.* 1043.). Let the chord FBD or F*bd* be given, and the abscissa BA or *b*A intersecting it (*fig.* 1043.) in B or *b* at a given angle. Draw the vertical line BA and FBD or F*bd* at the given angle on the plane. Fix one end of the chain at F, and from the point D or *d*, with another part of the chain, raise or lower the chain until the lower part coincide with A, and through points, made as before, draw the curve.

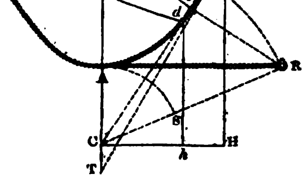


Fig. 1043.

To draw a tangent to the catenary: let DBF be a horizontal line, and at right angles to BA from A draw AR equal to the curve DA, obtained as before, and draw BR, which bisect in *o*. At right angles to BR draw *o*C intersecting BA continued in C. Draw CR, and make the angle BDT equal to the angle ACR. DT is the tangent required, and BC equals CR; CA is the tension at the point A, or the horizontal draft, which, in a catenary, is in every point the same, and is therefore a constant quantity; as DB : BT :: CA : AR;

or as DB : BT :: the constant quantity CA : AR, equal to the length of the chain AD.

If CH be drawn through C at right angles to BC it is called the directrix, and DH drawn parallel to BC, intersecting the directrix at H, is the tension at the point D, being always equal to the sum of the abscissa and constant quantity. With the centre C and radius = the tension DH at D = CB, cut the tangent at the vertex A in R, then AR is the length of the chain AD.

AC is the semi-axis of an equilateral hyperbola, and also the radius of curvature of a circle equicurved with it and the catenary.

In the triangle CAR, when CA is the radius, then the tension equals CR, the secant of the angle ACR (= BDC). The chain AD equals AR, the tangent of the same angle and the abscis AB equals CR − CA = SR. Hence, ACR being a right-angled triangle, it is manifest that when two of the five quantities, viz. *the angle, the abscis, the length of the chain between the vertex and point of suspension, the constant quantity or tension at the vertex, and the tension at the points of suspension*, are known, the other three may be obtained geometrically, or from a table of tangents and secants.

Catharine Wheel. In Gothic buildings an ornamented window or compartment of a window of a circular form, with rosettes or radiating divisions or spokes. In the cathedral at Rheims, the church of St. Omer at Rouen, in Winchester Cathedral, and the transepts of Westminster Abbey, are specimens, among many others, of this species of ornamental window.

Cathedral. (Gr. Καθεδρα, a seat or throne.) The principal church of a province or diocese, wherein the throne of archbishop or bishop is placed. It was originally applied to the seats in which the bishop and presbyters sat in their assemblies. In after times, the bishop's throne was, however, placed in the centre of the apsis, on each side whereof were inferior seats for the presbyters. In the present day the bishop's throne is placed on one side of the choir, usually on that towards the south.

Cathetus. (Gr. Καθετος, let down.) A perpendicular line passing through the centre of a cylindrical body as a baluster or a column. It is also a line falling perpendicularly, and passing through the centre or eye of the volute of the Ionic capital.

Cattle Shed, or Cattle House. In agricultural buildings an erection for containing cattle while feeding, or otherwise. The cattle shed is, of course, most economically constructed when built against walls or other buildings. If cattle sheds are built in isolated situations, the expense of a double shed will be much less than that of a single one, to contain the same number of cattle. Buildings of this description should be well ventilated, and be so constructed as to require the least possible labour in supplying the food, and clearing away the dung. The stalls should be placed so as to keep the cattle dry and clean, with sufficient drains to receive the ordure. There should be good provision of air holes in the roof; and, if the building have gables, a window should be placed in each as high as possible with moveable *luffer-boards*, as in granary windows, which may be easily opened and shut by means of a rope attached to a lever connected with them. These precautions will much tend to the health of the cattle, and even preserve the timbers, which in such buildings are peculiarly apt to rot at an early period after their erection, from the constant alternations of dryness and moisture.

Cattus. A moveable shed usually fixed on wheels.

Caulicolæ or Caulicoli. (Lat. Caulis, a stalk.) The eight lesser branches or stalks in the Corinthian capital springing out from the four greater or principal caules or stalks. The eight volutes of the capital of the order in question are sustained by four caules or leaves, from which these caulicolæ or lesser foliage arise. They have been sometimes confounded with the helices in the middle, and by others with the principal stalks whence they arise. Other definitions have been also incorrectly given, but not worth notice here.

Caulking or Cocking. The mode of fixing the tie-beams of a roof or the binding joists of a floor down to the wall-plates. Formerly this was performed by dovetailing in the following manner: — A small part of the depth of the beam at the end of the under side was cut in the form of a dovetail, and to receive it a corresponding notch was formed in the upper side of the wall-plate, across its breadth, making, of course, the wide part of the dovetail towards the exterior part of the wall, so that the beams, when laid in their notches, and the roof finished, would greatly tend to prevent the walls separating, though strained by inward pressure, or even if they should have a tendency to spread, through accidents or bad workmanship. But beams so fixed have been found liable to be drawn to a certain degree out of the notches in the wall-plates from the shrinking of the timber; a more secure mode has therefore been introduced, which obviates all hazard of one being drawn out of the other by any deficiency of seasoning in the timbers, or by any changes of weather.

Caustic Curve. (Gr. Καιω, to burn.) The name given to a curve, to which the rays of light, reflected or refracted by another curve, are tangents. The curve is of two kinds, the *catacaustic* and the *diacaustic*; the former being caused by reflection, and the latter by refraction.

Cavædium. (Lat.) In ancient architecture an open quadrangle or court within a house. The cavædia described by Vitruvius are of five species: — *Tuscanicum*, *Corinthium*, *Tetrastylon* (with four columns), *Displuviatum* (uncovered), and *Testudinatum* (vaulted). Some authors have made the cavædium the same as the atrium and vestibulum, but they were essentially different.

Cave. (Lat. Cavum.) A hollow place. Perhaps the oldest species of architecture on record.

Caveæ. (Lat.) In ancient architecture the subterranean cells in an amphitheatre, wherein the wild beasts were confined in readiness for the fights of the arena. In the end the amphitheatre itself (by synecdoche) was called cavea, in which sense it is employed by Ammianus Marcellinus, lib. xxix. cap. i.

Cavetto. (Lat. Cavus.) A hollowed moulding, whose profile is the quadrant of a circle. It is principally used in cornices.

Cedar. (Gr. Κεδρος.) The pinus cedrus of Linnæus, a forest tree little used in this country, except for cabinet work. See p. 484.

Ceiling. (Lat. Cœlum.) The upper horizontal or curved surface of an apartment opposite the floor, usually finished with plastered work. The subject of ceilings is treated of at length in Sect. 22. Chap. I. Book III.

Ceiling Floor. The joisting and ceiling supported by the beams of the roof.

Ceiling Joists. Small beams, which are either mortised into the sides of the binding joists, or notched upon and nailed up to the under sides of those joists. The last mode diminishes the height of the room, but is more easily executed, and is by some thought not so liable to break the plaster as when the ends of the ceiling-joists are inserted into *pulley mortises.*

Celer. See Architects, list of, 42.

Cell. (Lat. Cella.) In ancient architecture the part of a temple within the walls. It was also called the *naos*, whence our *nave* in a church. The part of a temple in front of the cell was called the *pronaos*, and that in the rear the *posticum.*

Cellar. (Fr. Cellier.) The lower story of a building, when wholly or partly under the level of the ground.

Cement. (Lat. Cementum.) The medium through which stones, bricks, or any other materials are made to adhere to each other. The different cements for stones and bricks, the most important in building, are treated of in Book II. Chap. II. Sect. 10.

Celtic Architecture. See Book I. Chap. II. Sect. 1.

Cemetery. (Gr. Κειμαι, I lie dead.) An edifice or area where the dead are interred. The most celebrated public cemeteries of Europe are those of Naples, of that in the vicinity of Bologna, of Pisa, and of the more modern ones of Paris, whereof that of Père la Chaise is the principal. That of Pisa is particularly distinguished by the beauty of its form and architecture, which is of early Italian Gothic. It is 490 feet long, 170 feet wide, and 60 feet high, cloistered round the four sides.

Cenotaph. (Gr. Κενος, empty, and Ταφος, a sepulchre.) A monument erected to the memory of a person buried in another place.

Centering. The temporary woodwork or framing whereon any vaulted work is constructed, sometimes called a *centre*. The principle upon which centering is constructed will be found under the heads of Mechanical Carpentry, Book II. Chap. I. Sect. 11. and of Practical Carpentry, Book II. Chap. III. Sect. 4.

Centre. (Lat. Centrum.) In a general sense denotes a point equally remote from the extremes of a line, superficies, or body, or it is the middle of a line or plane by which a figure or body is divided into two equal parts; or the middle point so dividing a line, plane, or solid, that some certain effects are equal on all its sides. For example, in a circle the centre is every where at equal distance from the circumference; in a sphere the centre is a point at the same distance from every point in the surface.

Centres of a Door. The two pivots on which the door revolves.

Centrolinead. An instrument for drawing lines converging to a point at any required distance, whether accessible or inaccessible.

Ceroma. (Gr.) An apartment in the Gymnasia and baths of the ancients, where the bathers and wrestlers were anointed with oil thickened by wax, as the name imports.

Cesspool, or **Sesspool.** A well sunk under the mouth of a drain to receive the sediment which might choke up its passage.

Chain Timbers. See Bond.

Chalcidicum. (Lat.) In ancient architecture a term used by Vitruvius to denote a large building appropriated to the purpose of administering justice, but applied sometimes to the tribunal itself. According to Festus, the name is derived from Chalcis, a city in Eubœa.

Chalk. (Germ. Kalk.) Earthy carbonate of lime, found in abundance in Great Britain, and, indeed, in most parts of the world. It is insoluble in water, but decomposed by heat, and sometimes used in masonry for the same purposes as limestone.

Chamber. (Fr. Chambre.) Properly a room vaulted or arched, but the word is now generally used in a more restricted sense to signify an apartment appropriated to lodging. With the French the word has a much more extensive meaning; but with us the almost only use of it, beyond what is above stated, is as applied in a palace to the room in which the sovereign receives the subject, which room is called the Presence Chamber.

Chamber of a Lock. In canals the space between the gates in which the vessels rise and sink from one level to another, in order to pass the lock.

Chamber Story. That story of a house appropriated for bed-rooms. In good houses it should never be less than ten feet high, in better houses from twelve feet to fifteen feet.

Chambers. See Architects, list of, 300.

Chambranle. (Fr.) An ornamental bordering on the sides and tops of doors, windows, and fireplaces. This ornament is generally taken from the architrave of the order of the building. In window frames the sill is also ornamental, forming a fourth side. The top of a three-sided chambranle is called the *transverse*, and the sides *ascendants*.

Chamfer. (Fr. Chamfrein.) The arris of anything originally right-angled cut a slope or bevel, so that the plane it then forms is inclined less than a right angle to the other planes with which it intersects.

Champain Line. In ornamental carved work formed of excavations is the line parallel to the continuous line, either ascending or descending.

Chancel. That part of the eastern end of a church in which the altar is placed. See Cancelli. This is the strict meaning; but in many cases the chancel extends much further into the church, the original divisions having been removed for accommodating a larger congregation. The word is also used to denote a separate division of the ancient basilica, latticed off to separate the judges and council from the audience part of the place.

Chandry. An apartment in a palace or royal dwelling for depositing candles and other lights.

Channel. (Fr. Canal.) A long gutter or canal sunk below the surface of a body.

Channel of the Larmier. See Canal of the Larmier.

Channel of the Volute. See Canal of the Volute.

Channel Stones. In paving are those prepared for gutters or channels, serving to collect and run off the rain water with a current.

Chantry. (Lat. Cantaria.) A little chapel in ancient churches with an endowment for one or more priests to say mass for the release of souls out of purgatory. In the fourteenth year of Edward VI. all the chantries in England were dissolved: at this period there were no less than forty-seven attached to St. Paul's Cathedral.

Chapel. (Lat. Capella.) A building for religious worship, erected separately from a church, and served by a chaplain. In Catholic churches, and in cathedrals and abbey churches, chapels are usually annexed in the recesses on the sides of the aisles. These are also called chantries.

Chapiter. The same as Capital, which see.

Chaplet. (Fr. Chapelet.) A moulding carved into beads, olives, and the like. See Baguette.

Chapter House. In ecclesiastical architecture the apartment (usually attached) of a cathedral or collegiate church in which the heads of the church or the chapter meet to transact business.

Chaptrel. (Fr.) The same as Impost, which see.

Charged. A term used to denote that one member of a piece of architecture is sustained by another. A frieze is said to be *charged* with the ornament cut on it.

Charnel House. A place where the bones of the dead are deposited.

Chartophylacium. A recess or apartment for the preservation of records or valuable writings.

Chase. An upright indent cut in a wall for the joining another to it, so as to hide light and exclude air.

Chase Mortise, or **Pulley Mortise.** A long mortise cut lengthwise in one of a pair of parallel timbers, for the insertion of one end of a transverse timber, by making the latter revolve round a centre at the other end, which is fixed in the other parallel timber. This may be exemplified in ceiling joists where the binding joists are the parallel timbers first fixed, and the ceiling are the transverse joists. See Practical Carpentry, in the body of the work.

Cheeks. Two upright, equal, and similar parts of any piece of timber-work. Such, for instance, as the sides of a dormer window.

Cheeks of a Mortise are the two solid parts upon the sides of the mortise. The thickness of each cheek should not be less than the thickness of the mortise, except mouldings on the stiles absolutely require it to be otherwise.

Cheese Room. A room set apart for the reception of cheeses after they are made. The walls should be lined, and fitted up with shelves with one or more stages, according to the size of the room, and proper gangways for commodious passage. In places where much cheese is manufactured, the dairy-room may be placed below, the shelf-room directly above, and lofts may be built over the shelf-room, with trap doors through each floor. This will save much carriage, and will be found advantageous for drying the cheeses.

Chequers. In masonry, are stones in the facings of walls, which have all their thin joints continued in straight lines, without interruption or breaking joints. Walls built in this manner are of the very worst description; particularly when the joints are made horizontal and vertical. Those which consist of diagonal joints, or joints inclined to the horizon, were used by the Romans.

Chesnut or Chestnut. The *fagus castanea.* A forest tree used in building. See p. 483.

Chest. The same as *caisson*, which see.

Chevron Work. A zigzag ornament used in the archivolts of Saxon and Norman arches (see *fig.* 188.). The outline of chevron work is a conjunction of right lines of equal lengths alternately disposed so as to form exterior and interior angles, and at the same time having all the angular points in the same straight line, or in the same curve line when the chevron work is used for ornamenting arches.

Chichele. See Architects, list of, 146.

Chimney. (Fr. Cheminée.) The place in a room where a fire is burnt, and from which the smoke is carried away by means of a conduit, called a flue. Chimneys are usually made by a projection from a wall, and recess in the same from the floor ascending within the limits of the projection and the recess. That part of the opening which faces the room is properly called the *fireplace*, the stone or marble under which is called the *hearth.* That on a level with and in front of it is called the *slab.* The vertical sides of the opening are called *jambs.* The head of the fore-plate resting on the jambs is called the *mantel*, and the cavity or hollow from the fireplace to the top of the room is called the *funnel.* The part of the funnel which contracts as it ascends is termed the *gathering*, by some the *gathering of the wings.* The tube or cavity, of a parallelogrammatic form, on the place from where the gathering ceases, up to the top of the chimney, is called the *flue.* The part between the gathering and the flue is called the *throat.* The part of the wall facing the room, and forming one side of the funnel parallel thereto, or the part of the wall forming the sides of the funnels where there are more than one, is the *breast.* In external walls, that side of the funnel opposite the breast is called the *back.* When there is more than one chimney in the same wall, the solid parts that divide them are called *withs:* and when several chimneys are collected into one mass, it is called a *stack of chimneys.* The part which rises above the roof, for discharging the smoke into the air, is called a *chimney shaft*, whose horizontal upper surface is termed the *chimney-top.*

The *covings* were formerly placed at right angles to the face of the wall, and the chimney was finished in that manner; but Count Rumford showed that more heat is obtained from the fire by reflection when the covings are placed in an oblique position. He likewise directed that the fire itself should be kept as near to the hearth as possible, and that the throat of the chimney should be constructed much narrower than had been practised, with the view of preventing the escape of so much heated air as happened with wide throats. If the throat be too near the fire, the draught will be too strong, and the fuel will be wasted; if it be too high up, the draught will be too languid, and there will be a danger of the smoke being occasionally beat back into the room.

Chimney Piece. See Book III. Chap. I. Sect. 22.

Chinese Architecture. See Book I. Chap. II. Sect. 8.

Chip. A piece of any material cut by an acute-angled instrument.

Chirosophus. See Architects, list of, 7.

Chisel. An instrument used in masonry, carpentry, and joinery, and also by carvers and statuaries, for cutting either by pressure or by impulse from the blows of a mallet or hammer. There are various kinds of chisels; the principal ones used in carpentry and joinery are the *former*, the *paring chisel*, the *gouge*, the *mortise chisel*, the *socket chisel*, and the *ripping chisel.*

Chiselled Work. In masonry, the state of stones whose surface is formed by the chisel.

Chit. An instrument used for cleaving laths.

Choir. (Gr. Χορος.) The part of a church in which the choristers sing divine service. In former times it was raised separate from the altar, with a pulpit on each side, in which the epistles and gospels were recited, as is still the case in several churches on the Continent. It was separated from the nave in the time of Constantine. In nunneries, the choir is a large apartment, separated by a grate from the body of the church, where the nuns chaunt the service.

Choragic Monument. (Gr. Χορος.) In Grecian architecture, a monument erected in honour of the choragus who gained the prize by the exhibition of the best musical or theatrical entertainment at the festivals of Bacchus. The choragi were the heads of the ten tribes at Athens, who overlooked and arranged the games at their own expense. The prize was usually a tripod, which the victor was bound publicly to exhibit, for which purpose a building or column was usually erected. The remains of two very fine monuments of this sort, viz. of Lysicrates and Thrasyllus, are still to be seen at Athens. See p. 69.

Chord. In geometry, the straight line which joins the two extremities of the arc of a curve; so called from the resemblance which the arc and chord together have to a bow and its string, the chord representing the string.

Chrismas. See Architects, list of, 263.

Christobolo. See Architects, list of, 154.

Chryses. See Architects, list of, 63.

Church. (Gr. Κυριακον, from Κυριος, Lord.) A building dedicated to the performance of Christian worship. For the general principles on which churches are to be designed see Book III. Chap. III. Sect. 3., also in Book I. Chap. II. Sect. 14. From these latter it will be seen that the basilicæ were the first buildings used for the assembly of the early Christians. Among the first of the churches was that of St. Peter at Rome, about the year 326, nearly on the site of the present church; and it is supposed that the first church of St. Sophia at Constantinople was built somewhat on its model. That which was afterwards erected by Justinian seems, in its turn, to have afforded the model of St. Mark's at Venice, which was the first in Italy constructed with pendentives and a dome, the former affording the means of covering a square plan with an hemispherical vault. The four most celebrated churches in Europe erected since the revival of the arts are, St. Peter's at Rome, which stands on an area of 227,069 feet superficial; Sta. Maria del Fiore at Florence, standing on 84,802 feet; St. Paul's, London, which stands on 84,025 feet, and St. Geneviève at Paris, 60,287 feet. The churches on the Continent are usually ranged under seven classes: *pontifical*, as St. Peter's, where the pope occasionally officiates; *patriarchal*, where the government is in a patriarch; *metropolitan*, where an archbishop is the head; *cathedral*, where a bishop presides; *collegiate*, when attached to a college; *parochial*, attached to a parish; and *conventual* when belonging to a convent. In this country the churches are cathedral, abbey, and parochial.

Ciborium. (Κιβωριον.) An insulated erection open on each side with arches, and having a dome of ogee form carried or supported by four columns. It is also the coffer or case in which the host is deposited.

Ciccione. See Architects, list of, 158.

Cilery. The drapery or foliage carved on the heads of columns.

Cill. (Sax. Cill.) The timber or stone at the foot of a door, &c. *Ground cills* are the timbers on the ground which support the posts and superstructure of a timber building. The name of cill is also given to the bottom pieces which support quarter and truss partitions.

Cimbia. A fillet string, list, or cornice.

Cimeliarch. A name given to the apartment where the plate and vestments are deposited in churches.

Cincture. The ring, list, or fillet at the top and bottom of a column, which divides the shaft of the column from its capital and base.

Cinquefoil. An ornament used in the pointed style of architecture; it consists of five cuspidated divisions or curved pendents inscribed in a pointed arch, or in a circular ring applied to windows and panels. The cinquefoil, when inscribed in a circle, forms a rosette of five equal leaves having an open space in the middle, the leaves being formed by the open spaces, and not by the solids or cusps.

Cione di Orgagna. See Architects, list of, 144.

Cippus. A small low column, sometimes without a base or capital, and most frequently bearing an inscription. Among the ancients the cippus was used for various purposes; when placed on a road it indicated the distance of places; on other occasions *cippi* were employed as memorials of remarkable events, as landmarks, and for bearing sepulchral epitaphs.

Circle. (Lat. Circulus.) A figure contained under one line called the circumference, to which all lines drawn from a certain point within it, called the centre, are equal. It is the most capacious of all plain figures.

Circular Buildings. Such as are built upon a circular plan. When the interior also is circular, the building is called a *rotunda*.

Circular Work. A term applied to any work with cylindric faces.

Circular Circular, or Cylindro-cylindric Work. A term applied to any work which is formed by the intersection of two cylinders whose axes are not in the same direction.

The line formed by the intersection of the surfaces is termed, by mathematicians, a *line of double curvature.*

Circular Roofs. Those whose horizontal sections are circular.

Circular Winding Stairs. Such as have a cylindric case or walled enclosure, with the planes of the risers of the steps tending towards the axis of the cylinder.

Circumference. The boundary lines of a circular body.

Circumscribe. (Verb.) To draw a line around a figure, or enclose it so that the enclosed shall be touched on all its angles or on its whole circumference by the line or body that encloses it.

Circumvolutions. The turns in the spiral of the Ionic capital, which are usually three, but there are four in the capitals of the temple of Minerva Polias.

Circus. (Lat.) In ancient architecture, a straight, long, narrow building, whose length to its breadth was generally as 5 to 1. It was divided down the centre by an ornamented barrier called the *spina*, and was used by the Romans for the exhibition of public spectacles and chariot races. Several existed at Rome, whereof the most celebrated was the Circus Maximus. Julius Cæsar improved and altered the Circus Maximus, and that it might serve for the purpose of a naumachia, supplied it with water. Augustus added to it the celebrated obelisk now standing in the Piazza del Popolo. Of this circus no vestiges remain. Besides these at Rome were the circi of Flaminius, near the Pantheon; Agonalis, occupying the site of what is now called the Piazza Navona; of Nero, on a portion whereof St. Peter's stands. Those of Antoninus and Aurelian, no longer even in ruins; but that of Caracalla, which was 738 feet in length, is at the present time sufficiently perfect to exhibit its plan and distribution in the most satisfactory manner. The spectacles of the circus were called the Circensian Games, and consisted of chariot and horse races, of both whereof the Romans were passionately fond, but particularly of the former, which in the times of the emperors excited so great an interest, as to divide the whole population of the city into factions, distinguished by the colours worn by the different charioteers. The disputes of these factions often led to serious disturbances.

Cissoid. In geometry a curved line invented by Diocles. Its name is derived from κισσος, ivy, from the curve appearing to mount along its assymptote, as ivy climbs on the trunk of a tree. The curve consists of two infinite branches above and below the diameter of a circle, at one of whose ends a tangent being drawn, the curve approaches the tangent without ever meeting it. The curve was invented by its author with a view to the solution of the famous problem of the duplication of the cube, or the insertion of two mean proportionals between two given straight lines. Its mechanical construction may be found in Newton's *Arithmetica Universalis.*

Cist. (Gr. Κιστη, a chest.) A term used to denominate the mystic baskets used in processions connected with the Eleusinian mysteries. It was originally formed of wicker work, and when afterwards made of metal, the form and texture were preserved in imitation of the original material. When sculptured on ancient monuments, it indicates some connection with the mysteries of Ceres and Bacchus.

Cistern. (Gr. Κιστη.) A reservoir for water, whether sunk below or formed of planks of wood above ground. In the construction of an earthen cistern, a well-tempered stratum of clay must be laid as a foundation for a brick flooring, and the bricks laid in terras mortar of Parker's cement. The sides must be built with the same materials; and if in a cellar or other place near a wall a space must be filled with clay, from the foundation to the top of the cistern contiguous to the wall, by which means it will be preserved from injury. Cisterns above ground are usually formed of wooden planks and carried by bearers; but the cistern formed of slates, now much used, is the best for adoption.

Civil Architecture. The art of erecting every species of edifice destined for the use of man, the several matters necessary to the knowledge whereof forms the subject of this work.

Civic Crown. A garland of oak leaves and acorns, often used as an architectural ornament.

Clamp. In brick-making a large mass of bricks generally quadrangular on the plan, and six, seven, or eight feet high, arranged in the brick field for burning, which is effected by flues prepared in stocking the clamp, and breeze or cinders laid between each course of bricks. See Book II. Chap. II. sect 9.

Clamp. In carpentry and joinery is a piece of wood fixed to another with a mortise and tenon, or a groove and tongue, so that the fibres of the piece thus fixed cross those of the other, and thereby prevent it from casting or warping.

Clamp Nails. See Nails.

Clasp Nails. See Nails.

Clathri. In ancient Roman architecture, were bars of iron or wood which were used to secure doors or windows.

CLAY. In ordinary language, any earth which possesses sufficient ductility to admit of being kneaded with water. Common clays may be divided into three classes, viz. *unctuous*, *meagre*, and *calcareous*. Of these the first is chiefly used in pottery, and the second and third are employed in the manufacture of bricks and tiles.

CLAYING. The operation of spreading two or three coats of clay for the purpose of keeping water in a vessel. This operation is also called *puddling*.

CLEAM. A term used in some places with the same signification as to stick or to glue.

CLEAR. The nett distance between two bodies, where no other intervenes, or between their nearest surfaces.

CLEAR STORY OR CLERE STORY. The upper vertical divisions of the nave, choir, and transepts of a church. It is *clear* above the roof of the aisles, whence it may have taken its name, but some have derived the name from the *clair* or light admitted through its tier of windows. Nearly all the cathedrals and large churches have *clear stories*, or tiers of arcades, and also of windows over the aisles and triforia. There is no triforium in the priory church of Bath, but a series of large and lofty windows constitute the clear story. The choir at Bristol Cathedral has neither triforium nor clear story.

CLEATS. Small wooden projections in tackle to fasten the ropes to.

CLEAVING. The act of forcibly separating one part of a piece of wood or other matter from another in the direction of the fibres, either by pressure or by percussion with some wedge-formed instrument.

CLEFTS. The open cracks or fissures which appear in wood which has been wrought too green. The carpenter usually fills up these cracks with a mixture of gum and sawdust, but the neatest way is to soak both sides well with the fat of beef broth, and then dip pieces of sponge into the broth and fill up the cracks with them; they swell out so as to fill the whole crack, and so neatly as to be scarcely distinguishable.

CLEOMENES. See ARCHITECTS, list of, 21.

CLEOPATRA'S NEEDLES. A name given to two obelisks on the east of the palace at Alexandria. They are of Thebaic stone and covered with hieroglyphics. One has been thrown down, broken, and lies buried in the sand. The other stands on a pedestal. They were each of a single stone, about sixty feet high and seven feet square.

CLEPSYDRA. (Gr. from Κλεπτω, to conceal, and Ὕδωρ, water). A water clock, or vessel for measuring time by the running out of a certain quantity of water, or sometimes of sand, through an orifice of a determinate magnitude. Clepsydras were first used in Egypt under the Ptolemies; they seem to have been common in Rome, though they were chiefly employed in winter. In the summer season sundials were used.

CLINCHING. The act of binding and driving backward with a hammer the pointed end of a nail after its penetration through a piece of wood.

CLINKERS. Bricks impregnated with nitre and more thoroughly burnt by being nearer the fire in the kiln. See p. 504.

CLOACÆ. The name given to the common sewers of ancient Rome for carrying off into the Tiber the filth of the city. The chief of these, called the Cloaca Maxima, was built by the first Tarquin of huge blocks of stone joined together without cement. It consisted of three rows of arches one above another, which at length conjoin and unite together. It began in the Forum Romanum, was 300 paces long, and entered the Tiber between the temple of Vesta and the Pons Senatorius. There were as many principal sewers as there were hills in the city.

CLOAK-PINS AND RAIL. A piece of wood attached to a wall, furnished with projecting pegs on which to hang hats, great-coats, &c. The pegs are called *cloakpins*, and the board into which they are fixed, and which is fastened to the wall, is called the *rail*.

CLOISTER. (Lat. Claustrum.) The square space attached to a regular monastery or large church with a peristyle or ambulatory round, usually with a covered range of building over. The cloister is perhaps, *ex vi termini*, the central square shut in or *closed* by the surrounding buildings. Cloisters are usually square on the plan, having a plain wall on one side, a series of windows between the piers or columns on the opposite side, and arched over with a vaulted or ribbed ceiling. It mostly forms part of the passage of communication from the church to the chapter house, refectory, and other parts of the establishment. In England all the cathedrals, and most of the collegiate churches and abbeys, were provided with cloisters. On the Continent they are commonly appended to large monasteries, and are often decorated with tombs and paintings in fresco.

A common appendage to a cloister was a *lavatory*, or stone trough for water, at which the monks washed their hands previous to entering the refectory.

CLOSER. The last stone in the horizontal length of a wall, which is of less dimensions than the rest to close the row. *Closers* in brickwork, or pieces of bricks (or *bats*), less or greater than half a brick, that are used to close in the end of a course of brickwork. In English as well as Flemish bond, the length of a brick being but nine inches, and its width four inches and a half, in order that the vertical joints may be broken at the end of the first stretcher, a quarter brick (or bat) must be interposed to preserve the continuity of the bond, this is called a *queen-closer*. A similar preservation of the bond may be obtained by inserting a three-quarter bat at the angle in the stretching course; this is called a *king-closer*. In both cases an horizontal lap of two inches and a half is left for the next header. See Book II. Chap. III. Sect. 2.

Close String. In dog-legged stairs, a staircase without an open newel.

Close or Cloos. See Architects, list of, 153.

Closet. A small apartment frequently made to communicate with a bed-chamber, and used as a dressing room. Sometimes a closet is made for the reception of stores, and is then called a *store closet*.

Clough or Cloyse. The same as *paddle*, *shuttle*, *sluice*, or *penstock*. A contrivance for retaining or letting out the water of a canal, pond, &c.

Clough Arches or Paddle-holes. Crooked arches by which the water is conveyed from the upper pond into the chamber of the lock of a canal on drawing up the *clough*.

Clout Nails. See Nails.

Clustered. The combination of several members of an order penetrating each other.

Clustered Columns. Several slender pillars or columns attached to each other so as to form one. In Roman architecture the term is used to denote two or four columns which appear to intersect each other, at the angle of a building or apartment, to answer to each return.

Coarse Stuff. In plastering, a mixture of lime and hair used in the first coat and floating of plastering. In floating more hair is used than in the first coat.

Coat. A thickness or covering of plaster or other work done at one time.

Cobarrubias. See Architects, list of, 210.

Cob-walls. Such as are formed of mud mixed with straw, not uncommon in some districts of England, but the best are to be found in Somersetshire.

Cocceius. See Architects, list of, 38.

Cocking or Cogging. See Caulking.

Cockle Stairs. A term sometimes used to denote a winding staircase.

Cœnaculum. (Lat.) In ancient Roman architecture, an eating or supper room. In the early period of their history, when the houses rarely consisted of more than two stories, it denoted generally the upper story. The word also signified lodgings to let out for hire, and also the upper stories of the circi, which were divided into small shops or rooms.

Cœnatio. An apartment in the lower part of the Roman houses, or in a garden, to sup or eat in. From Suetonius it would appear that it denoted a banqueting and summer house. In the Laurentine Villa a large cœnatio is described by the younger Pliny, and it seems, from the description, that it was placed in the upper part of a lofty tower.

Coffer. (Sax. Cofre.) A sunk panel in vaults and domes, and also in the soffite or under side of the Corinthian and Composite cornices, and usually decorated in the centre with a flower. But the application of the term is general to any sunk panel in a ceiling or soffite.

Coffer Dam. A case of piling, water-tight, fixed in the bed of a river, for the purpose of excluding the water while any work, such as a wharf, wall, or the pier of a bridge, is carried up. A coffer dam is variously formed, either by a single enclosure or by a double one, with clay, chalk, bricks, or other materials between, so as effectually to exclude the water. The coffer dam is also made with piles only driven close together, and sometimes notched or dove-tailed into one another. If the water be not very deep, piles may be driven at a distance of five or six feet from each other, and grooved in the sides with boards let down between them in the grooves. For building in coffer dams, a good natural bottom of gravel or clay is requisite, for though the sides be made sufficiently water-tight, if the bed of the river be loose, the water will ooze up through it in too great quantities to permit the operations to be carried on. It is almost unnecessary to inculcate the necessity of the sides being very strong and well-braced on the inside to resist the pressure of the water.

Cogging. See Caulking.

Coin. (Fr.) The same as *quoin*. The angle formed by two surfaces of a stone or brick building, whether external or internal, as the corner formed by two walls, or of an arch and wall, the corner made by the two adjacent sides of a room, &c.

Cole. See Architects, list of, 175.

Coliseum. The name given to the amphitheatre built (A. D. 72) by Vespasian. See body of the work, p. 94.

Collar or Colarino. (It.) A ring or cincture; it is another name for the astragal of a column. It is sometimes called the neck, gorgerin, or hypotrachelium.

Collar Beam. A beam used in the construction of a roof above the lower ends of the rafters or base of the roof. The tie beam is always in a state of extension, but the collar beam may be either in a state of compression or extension as the *principal rafters* are with or without tie beams. In trussed roofs, collar beams are framed into queen posts; in common roofs, into the rafters themselves.

In general, trusses have no more than one collar beam; yet, in very large roofs, they may have two or three collar beams besides the tie beam. The collar beam supports or trusses up the sides of the rafters, so as to keep them from sagging without any other support, but then the tie beam would be supported only at its extremities. In common purlin roofing, the purlins are laid in the acute angles between the rafters and the upper edges of the collar beams. See p. 546.

College. An establishment properly so termed for the education of youth in the higher branches of study. See Book III. Chap. III. Sect. 8.

Colonelli. (It.) The Italian name for the posts employed in any truss framing.

Colonnade. (It. Colonnata.) A range of columns. If the columns are four in number, it is called *tetrastyle*; if six in number, *hexastyle*; when there are eight, *octastyle*; when ten, *decastyle*; and so on, according to the Greek numerals. When a colonnade is in front of a building it is called a *portico*, when surrounding a building a *peristyle*, and when double or more *polystyle*. The colonnade is moreover designated according to the nature of the intercolumniations introduced as follows: *pycnostyle*, when the space between the columns is one diameter and a half of the column; *systyle*, when it is of two diameters; *eustyle*, when of two diameters and a quarter; *diastyle*, when three, and *aræostyle* when four.

Columbarium. (Lat.) A pigeon-house. The plural of the word (*columbaria*) was applied to designate the apertures formed in walls for the reception of cinerary urns in the ancient Roman cemeteries.

Columellæ. A name sometimes used for balusters.

Column. (Lat. Columna.) Generally any body which supports another in a vertical direction. For an account of the columns used in the five orders, see Book III. Chap. I. Sects. 2, 3, 4, 5, 6, and 7. There are various species of columns, as *twisted*, *spiral*, and *rusticated*. *Cabled* or *rudented* columns are such as have their flutings filled with cables or astragals to about one third of the height. *Carolitic* columns have their shafts foliated. Columns were occasionally used as monuments, as the Trajan and Antonine columns at Rome, and the Monument in London. By the side of the Halle au Blè at Paris there is a *gnomonic* column for showing the time, erected by Catharine di Medicis. The *Columna Bellica* at Rome was near the temple of Janus, and at it the consul proclaimed war by throwing a javelin towards the enemies' country. The *chronological* column was rather historical, bearing an inscription to record an event. The *cruciferal* column is one bearing a cross; the *funereal* one, an urn; the *zoophoric*, an animal; and the *itinerary* one pointed out the various roads diverging from its site. There was among the Romans what was called a *lacteal* column, which stood in the vegetable market, and contained on its pedestal a receptacle for infants abandoned by their parents. (Juvenal, *Sat.* vi.) On the *legal* column were engraved the laws; the *boundary* or *limitative* column marked the boundary of a province; the *manubial* column was for the reception of trophies or spoils; and the *rostral* column, decorated with prows of ships, was for the purpose of recording a naval engagement. The *triumphal* column was erected in commemoration of a triumph, and the *sepulchral* one was erected on a tomb. The *milliarium aureum*, or *milliary* column of the Romans, was originally a column of white marble, erected by Augustus in the Forum, near the temple of Saturn. From it the distances from the city were measured. It is a short column with a Tuscan capital, having a ball of bronze (formerly gilt for its finish) at top, and is still preserved in the Capitol.

Combination of the Parts of Buildings. See Book III. Chap. III. Sect. 1., and Book III. Chap. II. Sects. 4. and 6.

Comitium. (Lat.) A building which stood in the Roman Forum, wherein assemblies of the people were held. It occupied the whole space between the Palatine Hill, the Capitol, and the Via Sacra.

Commissure. (Lat.) The joint between two stones, or the application of the surface of one stone to the surface of another.

Common Centring. Such as is constructed without trusses, but having a tie beam at its ends. Also that employed in straight vaults.

Common Joists. Those in single naked flooring to which the boards are fixed. They are also called *boarding joists*, and should not exceed one foot apart.

Common Rafters. Those in a roof to which the boarding or lathing is attached.

Common Roofing. That which consists of common rafters only, which bridge over the purlins in a strongly framed roof.

Communication Doors. Those which, when open, throw two apartments into one.

Comparted. (Fr. Compartir, to divide.) That which is divided into several parts is said to be comparted.

Compartition. The distribution of the ground plot of an edifice into the various passages and apartments.

Compartment. A subdivisional part, for ornament, of a larger division. To this alone is the term properly applicable.

Compartmemt Ceiling. One divided into panels, which are usually surrounded by mouldings.

Compartment Tiles. An arrangement of varnished red and white tiles on a roof.

Compass Saw. One for dividing boards into curved pieces; it is very narrow and without a back.

Compasses. (Fr. Compas.) A mathematical instrument for drawing circles and measuring distances between two points. *Common compasses* have two legs, moveable on a joint. *Triangular compasses* have two legs similar to common compasses, and a third leg fixed to the bulb by a projection, with a joint so as to be moveable in every direction. *Beam compasses*, which see, are used for describing large circles. *Proportional compasses* have two pair of points moveable on a shifting centre which slides in a groove, and thereby regulates the proportion that the opening at one end bears to that of the other. They are useful in enlarging or diminishing drawings.

Complement. The number of degrees which any angle wants of a right angle. The complement of a parallelogram is two lesser parallelograms, made by drawing two right lines parallel to the sides of the quarter through a given point in the diagonal.

Compluvium. (Lat.) An area in the centre of the ancient Roman houses, so constructed that it might receive the waters from the roofs. It is also used to denote the gutter or eave of a roof.

Compo. A name often given to Parker's cement.

Composite Arch. The same as the pointed or lancet arch.

Composite Numbers. Such as can be divided by some other number greater than unity; whereas *prime numbers* admit of no such divisor.

Composite Order. See Book III. Chap. I. Sect. 7., and Book I. Chap. II. Sect. 13.

Composition, architectural. For general principles, see Book III. Chap. II. Sect. 1.

Composition of Forces. The combination or union of several forces for determining the result of the whole. See p. 381.

Compound Interest. See p. 280. 856.

Compressibility. The quality of bodies which permits of their being reduced to smaller dimensions. All bodies, in consequence of the porosity of matter, are compressible, but liquids resist compression with immense force.

Concamerata Sudatio. An apartment in the ancient gymnasium, between the *laconicum* or stove, and the warm bath. To this room the racers and wrestlers retired to wipe off the sweat from their bodies.

Concamerate. (Lat.) To arch over.

Concavity. (Lat. Concavus, hollow.) Of a curve line is the side between the two points of the curve next its chord or diameter. The concavity of a solid is such a curved surface, that if any two points in it be taken, the straight line between them is in a void space, or will coincide in only one direction with the surface.

Concentric. (Lat.) Having a common centre, as are the radii of a circle.

Conchoid of Nicomedes. A name given to a curve invented by that mathematician for solving the two famous problems of antiquity — the duplication of the cube, and the trisection of an angle. It continually approaches a straight line without meeting it, though ever so far produced.

Concrete. (Lat. Concrescere.) To coalesce in one mass. A mass composed of stone chippings or ballast, cemented together through the medium of sand and lime, and usually employed in making foundations where the soil is of itself too light or boggy, or otherwise insufficient for the reception of the walls. See Book II. Chap. II. Sect. 11.

Conduit. (Fr.) A long narrow walled passage underground, for secret communication between different apartments. It is a term also used to denote a canal or pipe for the conveyance of water, and is also applied to the structure to which it is conveyed for delivery to the public.

Cone. (Gr. Κωνος.) A solid body, having a circle for its base, and terminating in a point called its vertex; so that a straight line drawn from any point in the circumference of the base to the vertex will coincide with the convex surface. If the axis or straight line drawn from the centre of the base to the vertex be perpendicular to the base, it is termed a *right cone*; if not, it is an *oblique cone*.

Confessional. (Lat.) In Catholic churches the small cell wherein the priest sits to hear the confession of, and give absolution to, the penitent. It is usually constructed of wood and in three divisions, the central one whereof has a seat for the convenience of the priest.

Configuration. The exterior form or superficies of any body.

Congé. (Fr.) The same as Apophyge, which see.

Conic Sections. The figures formed by the intersections of a plane with a cone. They are five in number: a triangle, a circle, an ellipse, a parabola, and an hyperbola; the three last, however, are those to which the term is usually applied. See Book II. Chap. I. Sect. 5.

Conical Roof. One whose exterior surface is shaped like a cone.

Conisterium. (Gr. Κονιστηριον.) In ancient architecture, a room in the gymnasium and palæstra, wherein the wrestlers, having been anointed with oil, were sprinkled over with dust, that they might lay firmer hold on their antagonists.

Conjugate Diameters. The diameters in an ellipsis or hyperbola parallel to tangents at each other's extremities.

Conoid. (Gr. Κονοειδης.) Partaking of the figure of a cone. A figure generated by the revolution of a conic section round one of its axes. There are three kinds of conoids, the *elliptical*, the *hyperbolical*, and the *parabolical*, which are sometimes otherwise denominated by the terms *ellipsoid* or *spheroid*, *hyperboloid*, and *paraboloid*.

Conservatory. A building for preserving curious and rare exotic plants. It is made with beds of the finest composts, into which the trees and plants on being removed from the greenhouse, and taken from the tubs and pots, are regularly planted.

With respect to its construction, it is very similar to the greenhouse, but it must be more spacious, loftier, and finished in a superior style. The sides, ends, and roofs should be of glass, for the free admission of light, and for protection of the plants. It should be, moreover, seated on a dry spot, so as to receive during the day as much of the sun's heat as possible. It is to be provided with flues or boiling water pipes, to raise the temperature when necessary; there must also be contrivances for introducing fresh air when required. In summer time the glass roofs are taken off and the plants exposed to the open air; but these are restored always, if taken off, on the slightest indication of frost. The chief point in which conservatories differ from greenhouses is, that in the latter, the plants and trees stand in pots placed upon stages, whereas, in the former, they are planted in beds of earth surrounded with borders. See Greenhouse.

Console. The same as Ancones, which see.

Construction. Literally, the building up from the architect's designs; but amongst architects it is more particularly used to denote the art of distributing the different forces and strains of the parts and materials of a building in so scientific a manner as to avoid failure and insure durability. The second book of this work is devoted to the subjects involved in the science of construction.

Constructive Carpentry, or Practical Carpentry. See Book II. Chap. III. Sect. 4.

Contact. (Lat. Contactus.) In geometry the touching any figure by a line or plane which may be produced either way without cutting it.

Content. (Lat. Contentus.) The area or superficial quantity contained in any figure.

Contexture. (Lat. Contextus.) The inter-disposition, with respect to each other, of the different parts of a body.

Contignatio. In Roman carpentry the same as that which we term *naked flooring*.

Continued. A term used to express anything uninterrupted. Thus, an attic is said to be continued when not broken by pilasters; a pedestal is continued when, with its mouldings and dado or die, it is not broken under the columns; so of a socle, &c.

Contour. (It. Contorno.) The external lines which bound and terminate a figure.

Contract. An agreement attached to a specification for the performance of certain works.

Contuccio. See Architects, list of, 190.

Convent. (Lat. Conventus.) A building for the reception of a society of religious persons.

Conventual Church. One attached or belonging to a convent.

Convergent Lines. Such as, if produced, will meet.

Convex. (Lat. Convexus.) A form which swells or rounds itself externally. A convex rectilinear surface is a curved surface, in which a point being taken, a right line passing through it can only be drawn in one direction.

Coping. (Dutch, Cop, the head.) The highest and covering course of masonry or brickwork in a wall. Coping equally thick throughout is called *parallel coping*, and ought to be used only on inclined surfaces, as on a gable, for example, or in situations sheltered from the rain, as on the top of a level wall, which it is intended to cover by a roof. Coping thinner on one edge than on the other serves to throw off the water on one side of the wall, and is called *feather-edged coping*. Coping thicker in the middle than at the edges is called *saddle-backed coping*. This, of course, delivers each way the water that falls upon it. It is commonly used on the walls of a sunk area, on dwarf walls carrying an iron railing, and in the best constructed fence walls. In Gothic architecture, coping is either inclined upon the faces or plumb; in the former case the sides of the vertical section are those of an equilateral triangle with an horizontal base. It is sometimes in one inclined plane, terminated at top by an astragal, and at others in two inclined planes parallel to each other, whereof the upper is terminated at top by an astragal, and projects before the lower, which, like that on one inclined plane, changes its direction at the bottom into a narrow vertical plane projecting before the level sofite before the parapet. The inclined coping is occasionally used without the astragal. The sofite of a projection is said to cope over when it slants downwards from the wall.

Copper. (Cuprum, a corruption of Cyprium, having been originally brought from the island of Cyprus.) One of the metals used in building, but not now to the extent to which it was employed a few years back. See Book II. Chap. II. Sect. 7.

Corbeil. (Lat. Corbis, a basket.) A carved basket, with sculptured flowers and fruit, used as the finishing of some ornament. The name is given to the basket placed on the heads of caryatides, under the sofite of the architrave cornice. The term is also applied to the bell of the Corinthian capital.

Corbels, in castellated and Gothic architecture, are a range of stones projecting from a wall for the purpose of supporting a parapet or the superior projecting part of the wall. Two of their sides are vertical planes perpendicular to the face of the wall; the fronts are variously moulded. They perform the same office as the modillions of an order, but the term is confined to the pointed style.

The word corbel is sometimes used to denote a niche or hollow in a wall for the reception of a statue or bust. There is also another sense in which it is used, namely, to signify a horizontal range of stones or timber fixed in a wall or in the side of a vault, serving to sustain the timbers of a floor or of a vault. In old buildings many of the timber floors or contiguations were thus supported.

Corbel Steps are certain steps in the gables of old buildings.

Corbel Table. A series of semicircular intersecting arches for carrying a battlement, parapet, or cornice, and resting on corbels.

Cordon. The edge of a stone on the outside of a building.

Core. The interior part of anything. In walls of masonry there should be thorough stones at regular intervals, for strengthening the core, which is commonly composed of rubble stones, or, when they are not procurable, two bond stones lapped upon each other may be used, one from each face of the wall. Instead of each thorough stone we may lay two stones level on the upper bed, and one large stone in the core lapped upon both, observing that the tails of the two lower stones be right-angled; by this means the two sides of the wall will be completely tied together.

The core of a column is a strong post of some material inserted in its central cavity when of wood.

Corinthian Order. See Book III. Chap. I. Sect. 7., and Book I. Chap. II. Sect. 1.

Cornice. (Fr. Corniche.) Any moulded projection which crowns or finishes the part to which it is affixed. Thus, we speak of the cornice of an order, of a pedestal, of a pier, door, window, house, &c. The cornice of an order is a secondary member of the order itself, being the upper subdivision of the entablature.

Corona. (Lat.) A member of the cornice, with a broad vertical face, and usually of considerable projection. The solid, out of which it is formed, is commonly recessed upwards from its sofite, and this part by the English workmen is called the *drip*, because it facilitates the fall of the rain from its edge, by which the parts below it are sheltered. The situation of the corona is between the cymatium above, and the bed-moulding below. See Book III. Chap. I. Sect. 18.

Corps. A French term, which signifies the projecting part of a wall, and intended to form the ground for some decoration.

Corridor. (It. Corridore.) A gallery or passage round a quadrangle leading to the various apartments. Also, any gallery of communication to them.

Corsa. (Lat.) In ancient architecture, the name given by Vitruvius to any platband or square fascia whose height is greater than its projection.

Cortile. (It.) A small court or area, quadrangular or curved, in a dwelling-house, which is surrounded by the buildings of the house itself.

Cossutius. See Architects, list of, 29.

Cottage. (Sax. Cot.) A small house or dwelling for a poor person. See Book III. Chap. III. Sect. 24.

Cotte. See Architects, list of, 272.

Coucy. See Architects, list of, 127.

Counter Drain. A drain parallel to a canal or embanked water-course, for collecting the soakage water by the side of the canal or embankment to a culvert or arched drain under the canal, by which it is conveyed to a lower level.

Counterfort. (Fr.) A buttress or pier built against and at right angles to a wall to strengthen it.

Counter Gauge. In carpentry, the measure of the joints by *transferring*, as, for instance, the breadth of a mortise to the plan on the other timber, where the tenon is to be made to adapt them to each other.

Counter Lath. One placed between every couple of gaugedones.

Counterparts of a building are the similar and equal parts of the design on each side of the middle of the edifice.

Counter Sink. The sinking a cavity in a piece of timber or other material to receive a projection on the piece which is connected with it, as for the reception of a plate of iron or the head of a screw or bolt.

Coupled Columns. Those arranged in pairs half a diameter apart. See p. 267. 2605—2608.

Couples. A term used in the north to signify rafters framed together in pairs with a tie fixed above their feet. The *main couples* answer to the trusses.

Course. (Lat. Cursus.) A continued level range of stones or bricks of the same height throughout the face or faces of a building. *Coursed masonry* is that therefore wherein the stones are laid in courses. The *course of the face of an arch* is the face of the arch stones, whose joints radiate to the centre. The *course of a plinth* is its continuity in the face of the wall. A *bond course* is that whose stones are inserted into the wall farther than either of the adjacent courses, for the purpose of binding the wall together. A *coursing joint* is the joint between two courses.

Course, Heading, in brickwork, is that in which the bricks are laid with their short sides towards the face.

Course, Stretching, is that in which the bricks are all laid lengthwise.

Court. (Fr. Cour.) An uncovered area before or behind the house or in the centre of it, in which latter case it is often surrounded by buildings on its four sides.

Courts of Law. See Book III. Chap. III. Sect. 6.

Coussinet. (Fr. Cushion.) A stone placed upon the impost of a pier for receiving the first stone of an arch. Its bed is level below, and its surface above is inclined for receiving the next voussoir of the arch.

The word is also used for the part of the Ionic capital between the abacus and quarter round, which serves to form the volute, and it is in the capital thus called because its appearance is that of a cushion or pillar seemingly collapsed by the weight over it, and is bound with a strap or girdle called the baltheus.

Cove. Any kind of concave moulding or vault; but the term, in its usual acceptation, is the quadrantal profile between the ceiling of a room and its cornice.

Cove Bracketing. The wooden skeleton for the lathing of any cove; but the term is usually applied to that of the quadrantal cove, which is placed between the flat ceiling and the wall.

Cover. That part of a slate which is hidden or covered.

Cover Way. In roofing, the recess or internal angle left in a piece of masonry or brickwork to receive the roofing.

Coving, in old buildings, the projection of the upper stories of houses over the lower ones.

Coving of a Fire-place. See Chimney.

Cow-house. A building for the protection of cows from the inclemencies of the season.

Cozzo, Pietro di. See Architects, list of, 98.

Crab. A species of crane much used by masons for raising large stones; it is a wheel and axle mounted on a pair of sloping legs, three or four feet apart, the legs being inserted into a frame at the base, whereon, opposite to the weight to be raised, a load may be placed for gaining so great an amount of leverage as to overcome the weight to be raised. The rope for the tackle works round the axle, which is turned by pinion wheels to gain power.

Cradle. A name sometimes given to a centering of ribs and lattice for turning culverts.

Cradle Vault. A term used, but improperly, to denote a cylindric vault.

Cradling. The timber ribs and pieces for sustaining the lathing and plastering of vaulted ceilings. The same term is applied to the wooden bracketing for carrying the entablature of a shop front.

Cramp. An iron instrument about four feet long, having a screw at one end, and a moveable shoulder at the other, employed by carpenters and joiners for forcing mortise and tenon work together.

Crampern or Cramp Iron, usually called for shortness *cramp*, a piece of metal, bent at both extremities towards the same side, for fastening stones together. When stones are to be connected with a greater strength than that of mortar, a chain or bar of iron with different connecting knobs is inserted in a cavity, cut on the upper side of a course of stones across the joints, instead of single cramps across the joints of each two stones. Cramps are commonly employed in works requiring great solidity; but in common works they are applied chiefly to the stones of copings and cornices, and generally in any external work upon the upper surface or between the beds of the stone. All external work, liable to the injuries which weather inflicts, should be cramped. The most secure mode of fixing cramps is to let them into the stone their whole thickness, and to run them with lead; but in slight works it is sufficient to bed them in plaster, as is practised in chimney-pieces. In modern buildings iron is chiefly used. The practice is bad, from the liability of iron to rust and exfoliate: hence cast-iron is better than wrought, and should be of somewhat larger size than when wrought iron is employed. The Romans wisely used cramps of bronze, a material far better than either cast or wrought iron.

Crampoons. Hooked pieces of iron, something like double calipers, for raising timber or stones.

Crane. (Sax. Cpan.) A machine for raising heavy weights, and depositing them at some distance from their original place. The crane may be constructed of immense power, and is generally worked by human strength.

Crane-house. A building erected for the shelter of a crane. By the Building Act it is most absurdly required to be of brick.

Crapaudine Doors. Those which turn on pivots at top and bottom.

Creasing or **Tile Creasing.** Two rows of plain tiles placed horizontally under the coping of a wall, and projecting about an inch and a half on each side to throw off the rain water.

Crenelle. In Gothic architecture, the opening in an embattled parapet.

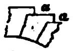
Crescent. A building, or rather a series of buildings, which on the plan is disposed in the arc of a circle.

Crest Tile. That on the ridge of a house. In Gothic architecture, crest tiles are those which, decorated with leaves, run up the sides of a gable or ornamented canopy.

Crib. The rack of a stable; sometimes applied to the manger. It is used also to express any small habitation; and moreover the stall or cabin of an ox.

Crocket. (Fr. Croc, a hook.) One of the small ornaments usually placed on the angles of pinnacles, pediments, canopies, &c., in Gothic architecture, and most commonly disposed at equal distances from each other. The crocket seems to have had for type the buds and boughs of trees in the spring season, from the great resemblance it bears to those periodical productions: examples, moreover, of the same ornament have great resemblance to the first stage of the leaves when the buds begin to open; sometimes, however, animals are substituted in the place of leaves.

Cromlechs. A mass of large flat stones laid across others in an upright position. Examples of cromlechs are found in Wales, Devonshire, Cornwall, and many exposed districts of England. For a further account of the cromlech, the reader may turn to Book I. Chap. II. Sect. 1.

Crosettes. (Fr.) The same as *ancones*, which see. In architectural construction the term is applied to the small projecting pieces *aa*  in arch stones, which hang upon the adjacent stones.

Cross. (Lat. Crux.) A figure consisting of four branches at right angles to each other, or a geometrical one, consisting of five rectangles, each side of one rectangle being common with one side of each of the other four. It is a figure more particularly used for the plans of churches than for those of other edifices. In ecclesiastical architecture, there are two kinds of plans having the form of a cross. The first is that wherein all the five rectangles are equal, or wherein each of the four wings is equal to the middle part formed by the intersection: this form is called a *Greek cross*. The second has only the two opposite wings equal, the other two are unequal, and the three rectangles in the direction of the unequal parts are of greater length than the three parts in the direction of the equal parts: this is the *Latin cross*. The middle part in each direction is common.

Cross, in Gothic architecture, an erection of various kinds, which may be classed as follows: — those used for marking boundaries, those which were memorials of remarkable events, monumental or sepulchral, as that at Waltham, and others of that nature; for preaching, as the ancient St. Paul's Cross; and market crosses, as at Winchester, Leighton Buzzard, &c.

Cross-banded. A term applied to handrailing, which is said to be cross-banded, when a × is laid upon its upper side, with the grain of the wood crossing that of the rail, and the extension of the veneer in the direction of its fibres is less than the breadth of the rail.

Cross Beam. A large beam going from wall to wall, or a girder that holds the sides of the house together.

Cross Garnets. Hinges having a long strap fixed close to the aperture, and also a cross part on the other side of the knuckle, which is fastened to the joint.

Cross-grained Stuff. Wood which has its fibres in a contrary direction to the surface, and which consequently cannot be perfectly smoothed by the operation of the plane, without turning either the plane or the stuff. This defect arises from a twisted disposition of fibres while in the act of growing.

Cross Springers. The ribs in the pointed style that spring from the diagonals of the pillars or piers.

Cross Vaulting. That formed by the intersection of two or more simple vaults. When each of the simple vaults rises from the same level to equal heights, the cross vaulting is denominated *a groin;* but when one of the simple vaults is below the other, the intersection is called *an arch* of that particular species which expresses both the simple arches. For example, if one cylinder pierce another of greater altitude, the arch so formed is termed a *cylindro-cylindric arch;* and if a portion of a cylinder pierce a sphere of greater altitude than the cylinder, the arch is called a *sphero-cylindric arch*, and thus for any species of arch whatever, the part of the qualifying word which ends in *o* denotes the simple vault having the greater altitude, and the succeeding word the other of less altitude.

Crow. A bar of iron used in bricklaying, masonry, and quarrying, and serving usually as a lever in its employment.

Crown. (Lat. Corona.) The uppermost member of any part. Thus, the upper member of a cornice, including the corona and the members above it, is so called.

Crown of an Arch. The most elevated line, or that can be assumed in its surface.

Crown or **Joggle Post**, is the same as *king post*, being the truss post that sustains the tie beam and rafters of a roof.

Crown Glass. The finest sort of window glass. See Book II. Chap. II. Sect. 11.

Crowning. The part that terminates upwards any piece of architecture, as a cornice, pediment, &c.

Crypt. (Gr. Κρυπτω, I hide.) The under or hidden part of a building. It is used also to signify that part of the ancient churches and abbeys appropriated below to the monuments of deceased persons.

Crypto-Porticus. In ancient architecture a concealed portico, also one that for coolness is enclosed on every side. Some of them were sunk some way into the ground. It also is a term applied to subterranean or dark passages and galleries in the Roman villas, often used as cool sitting rooms.

Cube. (Gr. Κυβος, a die.) A solid bounded by six square sides. It is also, from its six sides, called *hexahedron*.

Cubiculum. (Lat.) A chamber. A distinction is made by Pliny between the *cubiculum* and the *dormitorium*. The name was also applied to the royal pavilion or tent which was built in the circus or amphitheatre for the reception of the emperors.

Cubit. A linear measure, in ancient architecture, equal to the length of the arm from the elbow to the extremity of the middle finger, usually considered about eighteen English inches. The geometrical cubit of Vitruvius was equal to six ordinary cubits.

Cul de Four. (Fr.) A low vault spherically formed on a circular or oval plan. An oven-shaped vault.

Culmen. In ancient Roman architecture, the ridge-piece of the roof.

Culvert. An arched channel of masonry or brickwork built beneath the bed of a canal for the purpose of conducting water under it. If the water to be conveyed has nearly the same level as the canal, the culvert is built in the form of an inverted siphon, and acts on the principle of a water-pipe. The word also signifies any arched channel for water under ground.

Culver-tail. The same as **Dove-tail**, which see.

Cuneus. (Lat.) That part of the Roman theatre where the spectators sate.

Cupola. (It. from Cupo, hollow.) A term, properly speaking, which is confined to the *underside* or ceiling part of a dome. See **Dome**.

Cupboard. A recess in a wall, fitted with shelves as a receptacle for articles of the tea table.

Curb Roof. One formed of four contiguous planes, two whereof are externally inclined, the ridge being in the line of concourse of the two middle planes and the highest of the three lines of concourse. A roof of this construction (see p. 2035.) is frequently termed a *Mansard* roof, from the name of its inventor. Its principal advantage over other roofing arises from its giving more space in the garrets.

Curb for Brick Steps. A timber nosing, generally of oak, used not only to prevent the steps from wearing, but also from being dislocated or put out of their places. When the steps are made to return, the curb also returns, but when they profile against a wall, the ends of the curb or nosing pieces house at each end into the wall.

Curb Plate. A circular continued plate, either scarfed together or made in two or more thicknesses. The wall plate of a circularly or elliptically ribbed dome is called a *curb-plate*, as likewise the horizontal rib at the top, on which the vertical ribs terminate. The plate of a skylight, or a circular frame for a well, is also called a curb-plate. The name is moreover given to a piece of timber supported in a curb roof by the upper ends of the lower rafters for receiving the feet of the upper rafters, which are thence called *curb rafters*.

Curb-stones. Those in the foot-paving of a street which divide it from the carriage-paving, above which they are or ought to be raised.

Curia. (Gr.) A Roman council-house. The city and empire contained many curiæ.

The *curia municipalis*, or *domus curialis*, seems to have, in destination, resembled our Guildhall. The *curia dominicalis* was a sort of manor house.

CURLING STUFF. That which is affected from the winding or coiling of the fibres round the boughs of the tree where they begin to shoot out of the trunk. The double iron plane is the best for working it.

CURRENT. The necessary slope of a piece of ground or pavement for carrying off the water from its surface.

CURSOR. (Lat.) The point of a beam compass that slides backwards and forwards. Also the part of a proportional compass by which the points are set to any given ratio.

CURTAIL STEP. The first or bottom step by which stairs are ascended, ending at the furthest point from the wall, in which it is placed in a scroll; perhaps taking its name from the step curling round like a cur's tail.

CURVATURE. See RADIUS OF CURVATURE.

CURVE. (Lat. Curvus.) A line that may be cut by a straight line in more points than one.

CURVILINEAR. Bounded by curve lines; thus a curvilinear roof is one erected on a curved plan, circular, elliptical, or otherwise.

CUSHION RAFTER. See PRINCIPAL BRACE.

CUSP. (Lat. Cuspis.) One of the pendents of a pointed arch, or of the arched head of a compartment of such an arch, or one of the several pendents forming what may be termed a *polyfoil*. Two cusps form a trefoil, three a quatrefoil, and so on.

CUSTOM HOUSE. See Book III. Chap. III. Sect. 15. An edifice erected for the receipt of the customs' duties payable on the importation and exportation of merchandise.

CUT. In inland navigation, the same as canal, arm, or branch.

CUT BRACKETS. Those moulded on the edge.

CUT ROOF. One that is truncated.

CUT STANDARDS. For shelves, the upright pieces supporting shelves above a dresser when cut into mouldings.

CUT STONE. Hewn stone, or that which is brought into shape by the mallet and chisel.

CUTTING PLANE. A plane dividing or cutting a solid into two parts in any direction.

CYCLOGRAPH (Gr. Κυκλος and Γραφω.) In practical geometry, an instrument for describing the arc of a circle to any chord and versed sine, but chiefly used in flat segments, or those whose curvatures approach to straight lines.

CYCLOID. (Gr. Κυκλοειδης.) A figure described by rolling a circle upon a plane along a straight edge, until the point on the circle which touches the straight edge return again to it after a revolution. The point traces the curve called the *cycloid* or *trochoid*.

CYCLOPEAN BUILDINGS. See Book I. Chap. II. Sect. 2.

CYLINDER. (G. Κυλινδρον.) A solid whose base is a circle, and whose curved surface is every where at an equal distance from the axis or line supposed to pass through its middle. Its formation may be conceived to be generated by the revolution of a rectangular parallelogram about one of its sides. The cone, sphere, and cylinder have a remarkable relation to each other, first discovered by Archimedes, namely, that the cone is one third the cylinder having the same base and altitude; and the inscribed sphere two thirds of the cylinder; or the cone, sphere, and cylinder are to each other as the numbers 1, 2, 3. It is termed a *right cylinder* when the axis is at right angles to the base, but if at an oblique angle the cylinder is said to be oblique.

CYLINDRICAL CEILING or VAULTING. Vulgarly called a *waggon-headed ceiling*. One in the shape of the segment of a cylinder. The cylindrical ceiling appears to have been first used by the Romans. It admits of being pierced by *lunettes* for the admission of light, which form cylindro-cylindric arches, and is usually formed into panels or coffers. See p. 774.

CYLINDRICAL WORK. Any kind of work which partakes of the shape of a cylinder, of whatever material it be formed.

CYLINDROID. A solid which differs from a cylinder in having ellipses instead of circles for its ends or bases.

CYMA. (Gr. Κυμα, a wave.) A moulding taking its name from its contour resembling that of a wave, being hollow in its upper part and swelling below. Of this moulding there are two sorts, the cyma recta thus, just described, and the cyma reversa thus, wherein the upper part swells, whilst the lower is hollow. By the workmen these are called *ogees*.

CYMATIUM. (Gr.) The upper moulding of a cornice.

CYMBIA. The same as FILLET, which see.

CYPRESS. (Lat. Cupressus.) The wood of the cypress was valued for its hardness and durability by the ancient architects.

CYRIADES. See ARCHITECTS, list of, 54

CYRUS. See ARCHITECTS, list of, 36.

CYZICENUS. In ancient architecture, a large hall decorated with sculpture.

D.

Dado. The die or part in the middle of the pedestal of a column between the base and cornice. It is of a cubic form, whence the name of die. The term is also applied to that part of an apartment between the plinth and impost moulding.

Dairy. An apartment in a house, or a separate building, for the preservation of milk, and the manufacture of it into butter, cheese, or other dairy produce. When on a small scale, where the milk is only used for butter, the dairy may be a room on the north side of the dwelling, or form one of the offices connected with the kitchen court. The temperature of a dairy should be within the range of forty-eight to fifty-five degrees of Fahrenheit, with sufficient ventilation to discharge all smells and impurities of the air. A dairy on a large scale should be a detached building, in which case it should contain a milk-room, a churning-room, and a dairy scullery, or place for scalding the utensils. If cheese be to be made, a room is required for the cheese-press, and another for drying the cheeses.

Dais. (Fr.) The platform or raised floor at the upper end of a dining-hall, where the high table stood; also the seat with a canopy open for it, for those guests who sat at the high table.

Dam. Architecturally, a fence against water. See Coffer-dam.

Dampness. A moisture generally attendant on buildings finished hastily, on account of the materials, not being dry, carrying up the moisture by capillary attraction. A layer of powdered charcoal mixed with pitch or resin and powdered pitcoal laid over one of the courses of the wall near the foundations will prevent the evil.

Dance. See Architects, list of, 290.

Dance, George. See Architects, list of, 314.

Days or Bays. In Gothic architecture, the compartments in windows formed by the transoms or horizontal pieces and mullions or vertical pieces.

Dead Shore. A piece of timber worked up in brickwork to support a superincumbent mass until the brickwork which is to carry it has set or become hard.

Deafening Sound-boarding. The *pugging* used to prevent the passage of sound through wooden partitions.

Deal. (Sax. Delan, to divide.) Properly the small thickness of timber into which a piece of any sort is cut up; but the term is now, though improperly, restricted in its signification to the wood of the fir tree cut up into thicknesses in the countries whence deals are imported, viz. Christiana, Dantzic, &c. Their usual thickness is three inches, and their width nine. They are purchased by the hundred, which contains 120 deals, be their thickness what it may, reduced by calculation to a standard thickness of one inch and a half and to a length of twelve feet. *Whole deal* is that which is one inch and a quarter thick, and *slit deal* is half that thickness. See Board.

Decagon. (Gr. Δεκα, ten, and Γωνια, an angle.) A geometrical figure having ten sides and ten angles. If the sides and angles are all equal, the figure is a regular decagon, and capable of being inscribed in a circle.

Decastyle. See Colonade.

Decimal. (Lat.) A term applied to a system of arithmetic in which the scale of numbers proceeds by tens.

Decoration. The combination of ornamental objects which the desire for varying a form or forms brings together in many ways for embellishing those subjects which are the objects of art. See Book III. Chap. I. Sect. 1.

Deliquiæ. (Lat.) A term used by Vitruvius to designate the rafters which formed the ridge of the roof and threw the water on each side.

Demetrius. See Architects, list of, 4.

Density. (Lat. Densus, thick.) A term used in physics to denote the quantity of matter which a body contains under a given or determinate surface; for example, a cubic foot. The quantity of matter in a body is called its mass, and is measured by the weight of the body, to which it is always proportional; hence the density of a body is great in proportion as its weight is great, and its volume small; or the density of bodies is directly as their masses, and inversely as their volumes.

Dentils or Dentels. (Lat. Dentes, teeth.) The small square blocks or projections in the bed mouldings of cornices in the Ionic, Corinthian, Composite, and occasionally Doric orders; their breadth should be half their height; and, as Vitruvius teaches, the intervals between them two thirds of their breadth. In the Grecian orders they are not used under modillions.

Description of a Building. The same as Specification. See Book II. Chap. III. Sect. 13.

Descriptive Geometry. That which consists in the application of geometrical rules to the representation of the figures, and the various relations of the forms of bodies, according to certain conventional forms. It differs from perspective, on account of the representation being made in such a manner that the exact distance between the different points of the body represented can always be found, and consequently all the mathematical relations resulting from the form and position of the body may be deduced from the representation. See Book II. Chap. I. Sect. 6.

Design. (Lat. Designo.) The idea formed in the mind of an artist on any particular subject, which he transfers by some medium, for the purpose of making it known to others. Every work of design is to be considered either in relation to the art that produced it, to the nature of its adaptation to the end sought, or to the nature of the end it is destined to serve; hence its beauty is dependent on the wisdom or excellence displayed in the design, on the fitness or propriety of the adaptation, and upon the utility for the end. The considerations of design, fitness, and utility will be seen at large in Book III. Chap. I. Sects. 1, 2.

Destemper. See Distemper.

Details. A term usually applied to the drawings on a larger scale for the use of builders, and generally called *working drawings*. See Book II. Chap. IV. Sect. 4.

Determining Line. In the conic sections, a line parallel to the base of the cone; in the hyperbola this line is within the base; in the parabolic sections it forms a tangent to the base, in the elliptic it falls without it. In the intersecting line of a circle, the determining line will never meet the plan of the base to which it is parallel.

Detrianus. See Architects, list of, 49.

Dexiphanes. See Architects, list of, 35.

Diaconicon. A place contiguous to the ancient churches, wherein were preserved the sacred vestments, vessels, relics, and ornaments of the altar. In modern language, the sacristy.

Diagonal. (Gr. Δια, through, and Γωνια, angle.) A straight line drawn through a figure joining two opposite angles. The term, in geometry, is used in speaking of four-sided figures, but it is nevertheless properly applied with reference to all polygons whereof the number of sides is not less than four. The term diameter is used by Euclid in the same sense; but modern geometers use the term diameter only in speaking of curve lines, and diagonal when speaking of angular figures.

Diagonal Scale. A compound scale formed by vertical and horizontal subdivisions with diagonals drawn across them, whereby we are enabled to measure off very small parts by means of equidistant parallels crossing others of the same kind.

Diagram. (Gr. Διαγραμμα, from Δια, through, and Γραφω, I write.) The figure or scheme for the illustration of a mathematical or other proposition.

Diagraph. (Gr.) A recently invented French instrument for drawing objects from nature.

Diameter. (Gr. Δια, through, and Μετρον, a measure.) A straight line passing through the centre of a geometrical figure, as that of a circle, ellipse, or hyperbola. The term is architecturally used to express the measure across the lower part of the shaft of a column, and is usually divided into sixty parts, called minutes, which form the scale for the measurement of all the parts of an order.

Diamond Pavement. One disposed in squares arranged diagonally.

Diastyle. (Gr. Δια and Στυλος, a column.) That distance between columns which consists of three diameters, or, according to some, of four diameters. The term is sometimes used adjectively, to signify that the building is arranged with those intervals between the columns.

Diatoni. (Gr. Δια and Τονος, an extension.) In ancient architecture the angle stones of a wall, wrought on two faces, and which, from stretching beyond the stones above and below them, made a good bond or tie to the work.

Diazoma. (Gr. Δια, through, and Ζωμα, a cincture.) In ancient architecture, the landings or resting places which, at different heights, encircled the amphitheatre like so many bands or cinctures, whence the name.

Dicasterium. (Gr. Δικη, justice.) In ancient architecture, the name of a tribunal or hall of justice.

Dictyotheton. (Gr. Δικτυον, a net, and Τιθημι, I place.) In ancient architecture, masonry worked in courses, like the meshes of a net. Also open lattice work, for admitting light and air.

Didoron. See Brick.

Die of a Pedestal. That part included between the base and the cornice.

Digging. In soft ground, one man with a spade will throw up, per hour, a cubic yard of twenty-seven feet. If a mattock must be used, the same quantity will require two men, and in a strong gravel, three. It will require three men to wheel thirty cubic yards of gravel in a day to the distance of twenty yards.

Diglyph. (Gr. Δις, twice, and Γλυφω, I carve.) A projecting face, with two panels or channels sunk thereon.

Dilapidation. The state of decay and ruin into which a building has been permitted to fall.

Dimension. (Lat. Dimetior.) In geometry is either length, breadth, or thickness. Thus a line has one dimension, as of length; a superficies has two, length and breadth; a solid has three dimensions, length, breadth, and thickness.

Diminished Arches. Those lower or less than a semicircle, called by the French *voutes surbaissées*.

Diminished Bar of a Sash. One thinner on the edge towards the room than on that towards the glass of the window.

Diminished Column. A column whereof the upper diameter is less than the lower.

Diminishing Rule. A board cut with a concave edge, so as to ascertain the swell of a column, and to try its curvature.

Diminishing Scale. A scale of gradation used in finding the different points for drawing the spiral curve of the Ionic volute, by describing the arc of a circle through every three preceding points, the extreme point of the last arc being one of the next three. Each point through which the curve passes is regulated so as to be in a line drawn to the centre of the volute, and the lines at equal angles with each other.

Diminution of a Column. The continued contraction of the diameter of the column as it rises. Most of the modern authors make the diminution to commence from one third of the height of the column; but in all the ancient examples the diminution commences from the bottom of the shaft. See Entasis. In Gothic architecture neither swell nor diminution is used, all the horizontal sections being similar and equal.

Dining or Dinner Room. Generally one of the largest rooms in a dwelling-house. In large buildings it extends to forty or fifty feet in length, and the breadth is from half to three fourths the length. In middle-sized houses, dining-rooms run from twenty-four down to eighteen feet in length by eighteen to sixteen feet in width, and thirteen or fourteen feet in height. In houses, the largest room on the ground-floor should be appropriated to the purpose.

Dinocrates. See Architects, list of, 22.

Dioti Salvi. See Architects, list of, 94.

Dipteral. (Gr. *Δίπτερος*, double-winged.) In ancient architecture, a temple having a double range of columns on each of its flanks. See Temple.

Direct Radial. In perspective, a right line from the eye perpendicular to the picture.

Directing Line. In perspective, the line in which an original plane would cut the directing plane.

Directing Plane. In perspective, a plane passing through the point of sight, or the eye, parallel to the picture.

Directing Point. In perspective, that in which any original line produced acts as the directing plane.

Director of an Original Line. In perspective, the straight line passing through the directing point and the eye of a spectator.

Director of the Eye. The intersection of the plane with the directing plane perpendicular to the original plane and that of the picture, and hence also perpendicular to the directing and vanishing planes, since each of the two latter is parallel to each of the two former.

Directrix. In geometry the name given to a certain straight line perpendicular to the axes of a conic section. One of the properties of these curves is that the distance of any point of the curve from the directrix is to the distance of the same point from the focus in a constant ratio. The name is sometimes applied generally to any straight or curved line required for the description of any curve.

Discharge. (Fr. Décharger.) The relief given to a beam, or any other piece of timber, too much loaded by an incumbent weight of building. When the relief is given, the weight is said to be discharged.

Discharging Arches. Those built over wooden lintels, whereby the bearing upon them is taken off. The chords of discharging arches are not much longer than the lintel, being the segments of very large circles. A temporary arch is frequently introduced, and removed on completing the building. Sometimes the arches are built without any lintel under them.

Dishing out. The same as Cradling, which see.

Displuviatum. (Lat.) In ancient architecture, a place from which the rain is conveyed away in two channels. According to Vitruvius, a *cavædium displuviatum* was an open court exposed to the rain.

Disposition. (Lat.) One of the essentials of architecture. It is the arrangement of the whole design by means of ichnography (plan), orthography (section and elevation), and scenography (perspective view). It differs from distribution, which signifies the particular arrangements of the internal parts of a building.

Distance of the Eye. In perspective, the distance of the eye from the picture in a line perpendicular to the plan thereof.

Distance, Point of. In perspective, the distance of the picture transferred upon the vanishing line from the centre, or from the point where the principal ray meets it; and thus it is generally understood to be on the vanishing line of the horizon.

Distance of a Vanishing Line. The length of a perpendicular falling from the eye perpendicular to the vanishing plane.

Distemper. (Fr. Detemper.) In painting, a preparation of opaque colour, ground up with size and water.

Distribution. (Lat.) The arrangement of the various apartments of a building.

Ditriglyph. (Gr. Δις, twice, Τρεις, three, and Γλυφω, I carve.) An arrangement of intercolumniations in the Doric order, by which two triglyphs are obtained in the frieze between the triglyphs that stand over the columns.

Dodecagon. (Gr. Δωδεκα and Γωνια, an angle.) A regular polygon of twelve equal sides.

Dodecahedron. (Gr. Δωδεκα and Ἑδρα, a seat.) One of the five platonic bodies, or regular solids, its surface being composed of twelve equal and regular pentagons.

Dog-legged Stairs. Such as are solid between the upper flights, or such as have no well-hole, and in which the rail and balusters of both progressive and retrogressive flight fall in the same vertical plane. The steps are fixed to strings, newels, and carriages; and the ends of the steps in the inferior kind only terminate on the side of the string without any housing.

Dome. (Lat. Domus.) The spherical, or other figure, convex roof over a circular or polygonal building. A *surbased* or *diminished dome* is one that is segmental on its vertical section, a *surmounted dome* is one that is higher than the radius of its base. There is great variety in the forms of domes, both in plan and section. In the former, they are circular and polygonal; in the latter, we find them semicircular, semi-elliptical, segmental, pointed, sometimes in curves of contrary flexure, bell-shaped, &c. The oldest dome on record is that of the Pantheon at Rome, which was erected under Augustus, and is still perfect. Below is a list of the principal domes in Europe, with their dimensions; the heights in the third column are from the ground: —

Place.	Feet Diam.	Feet High.
Pantheon at Rome - - - - - -	142	143
Duomo, or Sta. Maria del Fiore, at Florence -	139	310
St. Peter's at Rome - - - - - -	139	330
Sta. Sophia at Constantinople - - -	115	201
Baths of Caracalla (ancient) - - - - -	112	116
St. Paul's, London - - - - - -	112	215
Mosque of Achmet - - - - - -	92	120
Chapel of the Medici - - - - - -	91	199
Baptistery at Florence - - - - - -	86	110
Church of the Invalids at Paris - - -	80	173
Minerva Medica at Rome - - - - -	78	97
Madonna della Salute, Venice - - -	70	133
St. Généviève at Paris (Pantheon) - - -	67	190
Duomo at Siena - - - - - - -	57	148
Duomo at Milan - - - - - - -	57	254
St. Vitalis at Ravenna - - - - - -	55	94
Val de Grace at Paris - - - - - -	55	133
San Marco, Venice - - - - - -	44	

Donjon. (Fr.) The massive tower within ancient castles to which the garrison might retreat in case of necessity. It was centrally placed, and frequently raised on an artificial elevation.

Dooks. The same as Wooden Bricks, which see. It is a Scotch term.

Door. (Sax. Doꞃ, Gr. Θυρα.) The gate or entrance of a house or other building, or of an apartment in a house. It must be proportioned to the situation and use for which it is intended. Thus, for an ordinary dwelling-house, a door should not be less than seven to eight feet high, and three to four feet broad; but to churches and public buildings the entrance-doors should be much wider, to allow of a multitude to pass out. So in stately mansions, the doors must be from six to twelve feet in width, and of proportionate height. For the different sorts and profiles of doors, see Book III. Chap. III. Sect. 19.

Door Frame or **Case.** The wooden frame enclosing a door.

Doric Order. See Book III. Chap. I. Sect. 4., and Book I. Chap. II. Sect. 4.

Dormant Tree or Summer. The lintel of a door, window beam, &c. A beam tenoned into a girder to support the ends of joists on both sides of it. *Summer*, in some parts, is the common term for a girder.

Dormer. A window placed on the inclined plane of the roof of a house, the frame being placed vertically on the rafters.

Dormitory. (Lat. Dormio, I sleep.) A large sleeping-room, capable of containing many beds.

Doron. See Brick.

Dove-house, or Dove-cot. A building for keeping tame pigeons, the only essential difference between which and a common poultry house is, that the entrance for the birds must be placed at a considerable height from the ground, because of the flight of pigeons being so much higher than other birds.

Dove-tail (from its spreading like a pigeon's tail). A joint used by carpenters and joiners in connecting two pieces of wood, by letting one into the other, in the form of the expanded tail of a dove. It is the strongest method of joining masses, because the tenon or piece of wood widens as it extends, so that it cannot be drawn out, because the tongue is larger than the cavity through which it would have to be drawn. The French call this method *queue d'hironde*, or swallow's tail.

Double Curvature. The curvature of a curve, whereof no part can be brought into a plane, such as the cylindro-cylindric curve, &c.

Double Floor. One constructed of binding and bridging joists. See p. 541.

Double-hung Sashes. See p. 572, 573.

Double Vaults. Two vaults of brick or stone carried up separately with a cavity between them.

Doubling. A term used in Scotland to denote eaves' boards.

Doucine. The French term for the cyma recta.

Dowels. Pins of wood or iron used at the edges of boards in laying floors, to avoid the appearance of the nails on the surface. Floors thus laid are called *dowelled floors*.

Drag. (Verb.) A term applied to anything bearing down or rubbing on another. Thus, a door is said to drag when its hinges become so loosened that the lower edge rubs upon the floor.

Dragon Beam or Piece. In carpentry, a short beam or piece of timber, lying diagonally with the wall-plates at the angles of a roof for receiving the heel or foot of the hip rafter. It is fixed at right angles with another piece, called the *angle tie*, which is supported by each returning wall-plate, on which it is cocked down.

Drain. A subterraneous or other channel for waste water. See Book II. Chap. III. Sect. 1.

Draught. The representation of a building on paper, explanatory of the various parts of the interior and exterior, by means of plans, elevations, and sections, drawn to a scale, by which all the parts are exhibited in the same proportion as the parts of the edifice intended to be represented.

Draught. In masonry, a part of the surface of the stone, hewn to the breadth of the chisel on the margin of the stone according to the curved or straight line to which the surface is to be brought. When the draughts are framed round the different sides of the stone, the intermediate part is wrought to the surface by applying a straight edge or templet. In very large stones, when the substance needs much reduction, it is usual to make several intermediate parallel *draughts*, and thus the intermediate parts may be hewn down nearly by the eye, without much application of the straight edge or templet.

Draught Compasses. Those with moveable points.

Draw Bore. (Verb.) The pinning a mortise and tenon, by piercing the hole through the tenon nearer to the shoulder than the holes through the cheeks from the abutment in which the shoulder is to come in contact.

Draw Bore Pins. Pieces of steel in the shape of the frustrum of a cone, rather taper, and inserted in handles with the greatest diameter next to the handle, for driving through the draw bores of a mortise and tenon in order to bring the shoulder of the rail close home to the abutment on the edge of the style. When this is effected, the draw bore pins, when more than one are used, are taken out singly, and the holes immediately filled up with wooden pegs.

Drawbridge. One made with long and heavy levers to raise or let it down at pleasure.

Drawing. See Book II. Chap. IV. Sect. 1.

Drawing is the art of representing any object by means of lines circumscribing its boundaries. For working drawings see Book II. Chap. IV. Sect. I.

Drawings necessary in Compositions. Book III. Chap. II. Sect. 2.

Drawing Room, perhaps more properly Withdrawing Room. The apartment to which the company *withdraw* after dinner.

Dressed. A term in masonry which expresses the operation a stone has undergone before building it in the wall, whether by the hammer only or by the mallet and chisel, and then rubbing the face smooth. In Scotland the term is used to signify hammer dressing only.

Dresser. A table placed against a wall in a kitchen, usually with drawers, and having shelves over it.

Dressing Room. A room generally adjoining to and communicating with the sleeping room, used, as the name implies, for dressing in. It should have a separate door to open on the lobby or passage of communication.

Dressings. All kinds of mouldings beyond the naked walls or ceilings are called by the general name of dressings. In joinery it is a term applied to the architraves or other appendages of apertures.

Drift. (Sax. Dꞃıꝼan.) The horizontal force which an arch exerts with a tendency to overset the piers from which it springs.

Drip. See Corona.

Dripping Eaves. (Dan. Dripper, to drop.) The lower edges of a roof wherefrom the rain drips or drops to the ground. By the Building Act dripping eaves are prohibited within the bills of mortality, towards any street or public way.

Drops. (Sax. Dꞃoppan.) The frusta of cones in the Doric order, used under the triglyphs in the architrave below the tænia. They are also employed in the under part of the mutuli or modillions of the order. In the Greek examples they are sometimes curved a little inwards on the profile.

Droved Ashlar. A term used in Scotland for chiselled or random tooled ashlar. It is the most inferior kind of hewn work in building. What is in that country called broached work is sometimes done without being droved; but in good broached work the face of the stone should be previously droved, and then broached.

Droved and broached. A term used in Scotland to signify work that has been roughed and then tooled clean.

Droved and striped. Work that is first droved and then striped. The stripes are shallow grooves done with a half or three-quarter inch chisel, about an eighth of an inch deep, having the droved interstices prominent. This and the two preceding sorts of work are not much used in the southern part of England.

Drueli. See Architects, list of, 166.*

Druidical Architecture. See Book I. Chap. II. Sect. 1.

Drum. (Dan. Tromme.) The upright part under or above a cupola. The same term is sometimes applied to the solid part or vase of the Corinthian and Composite capitals.

Dry Rot. A disease of timber which destroys the cohesion of its parts; it is usually ascribed to the attacks of fungi, such as the *Polyporus destructor* and *Merulius lacrymans*, whose spawn appears upon the surface overspreading it like a tough thick skin of white leather; and there is no doubt of its being often connected with the appearance of such fungi. Dry rot is, however, in some cases to be identified with the presence of fungi of a more simple kind than those just mentioned, such as those of the genus *Sporotrichum*. See p. 490.

Dubbing out. A term used by plasterers to signify the bringing of an uneven surface to a plane by pieces of tile, slate, plaster, or the like.

Dunstan. See Architects, list of, 75.

Duodecimal. (Lat. Duodecim.) Proceeding by twelves. It is a term applied to an operation in arithmetic, which is explained in p. 296, *et seq.*

Dwang. A term used in Scotland to denote the short pieces of timber employed in strutting a floor.

Dwarf Wainscoting. Such as does not reach the whole height of a room, being usually four, five, or six feet high.

Dwarf Walls. Low walls of less height than the story of a building; sometimes the joists of a ground floor rest upon dwarf walls. The enclosures of courts are frequently formed by them with a railing of iron on the top; and indeed any low wall used as a fence is a dwarf wall.

Dwelling House. See p. 810, *et seq.*

Dwellings, different early sorts of. See Book I. Chap. I. Sect. 3.

Dye. See Die.

Dynamics. (Gr. *Δυναμις*, force or power.) As generally understood, the science which treats on the motion of bodies, because it is only known to us by the motion it produces in the body on which it acts. It is however usually restricted to those circumstances of motion in which the moving bodies are at liberty to obey the impulses communicated to them; the opposite cases, or those in which the bodies, whether by external circumstances or by their connection with one another, are not at liberty to obey the impulses given, being within the science of mechanics.

E.

Eagle. (Gr. Αιετος.) A term used by the Greeks for the frontispiece or pediment of their temples.

Ears. The same as Crosettes, which see.

Earnulph. See Architects, list of, 80.

Eaubald. See Architects, list of, 70.

Eaves. (Probably Fr. Eaux.) The lowest edges of the inclined sides of a roof which project beyond the face of the walls, so as to throw the water off therefrom, that being their office.

Eaves' Board, Eaves' Lath, Eaves' Catch. See Arris Fillet.

Ebony. The wood of a natural order of shrubby or arborescent exogens, chiefly inhabiting the tropics. Some species are remarkable for the hardness and blackness of their wood, which is principally used for furniture.

Eccentricity. The difference of centre from another circle. The distance between the foci of an ellipse.

Echea. (Gr. Ηχεω, I sound.) In ancient architecture, sonorous vessels of metal or earth, in the form of a bell, used in the construction of theatres for the purpose of reverberating the sound of the performer's voice. They were distributed between the seats, and are described in the fifth book of Vitruvius, who states that Minnimus introduced them in Rome, after the taking of Corinth, where he found this expedient used in the theatre.

Echinus. (Gr. Εχινος.) The same as the ovolo or quarter round, though the moulding is only properly so called when carved with eggs and anchors. (See Anchor.) It is the shell or husk of the chestnut, though the ornament does not seem to bear much resemblance to it.

Ecphora. (Gr. Εκ, out, Φέρω, I bear.) A word used by Vitruvius (lib. iii. cap. 3.,) to signify the projecture of a member or moulding of a column, that is, the distance of its extremity from the naked of the column, or, according to others, from the axis.

Ectype. (Gr. Εκτυπον.) An object in relievo, or embossed.

Edge. (Sax. Ecge.) The intersection of two planes or surfaces of a solid, which therefore is either straight or curved according to the direction of the surfaces. See Arris. It is also that side of a rectangular prismatic body which contains the length and thickness; but in this sense of the term, the body to which it applies is generally understood to be very thin; thus we say " the edge of a door," " the edge of a board," meaning the narrow side. The edge of a tool is the meeting of the surfaces when ground to a very acute angle.

Edge Tools are those which clip or shave in the operation of working.

Edging. In carpentry, the reducing of the edges of ribs or rafters, whether externally or internally, so as to range in a plane or in any curved surface required. *Backing* is a particular use of edging, and only applies to the outer edges of ribs or rafters; but edging or ranging is a general term, and applies either to the backing or internal surface. See Backing.

Edifice. (Lat. Ædificium.) A word synonymous with fabric, building, erection; the word is, however, more usually employed to denote architectural erections distinguished for grandeur, dignity, and importance.

Ednoth. See Architects, list of, 74.

Effect. (Lat. Efficio.) That quality in works of art whose nature is to give particular efficacy to other qualities, so as to bring them out and attract the eye of the spectator.

Egbert. See Architects, list of, 68.

Egg and Tongue. Ornaments used in the echinus, supposed by Quatremère de Quincy to have had their origin in the head of Isis, and, as he imagines, representing a mystical collar or necklace of the mundane egg and the tongue of the serpent of immortality; but as we think, in the representation of much more simple objects, those of nature herself. See Echinus.

Egyptian Architecture. See Book I. Chap. II. Sect. 7.

Egyptian Hall. See Œcus.

Elæothesium. (Gr. Ελαιον, oil.) In ancient architecture, an apartment in the baths wherein, after leaving the bath, the bathers anointed themselves.

Elastic Curve. In mechanics, the figure assumed by an elastic body, one end whereof is fixed horizontally in a vertical plane, and the other loaded with a weight which, by its gravity, tends to bend it.

Elasticity. (Gr. Ελαστη, a spring, from Ελαυνω, I draw.) In physics that property possessed by certain bodies of recovering their form and dimensions after the external force which has dilated or compressed them is withdrawn. It is only perfect when the body recovers exactly its primitive form after the force to which it has been subjected has been removed, and that in the same time as was required for the force to produce the alteration. This is however a quality not strictly found in nature.

Elbows. (Sax. Elboga.) The upright sides which flank any pannelled work, as in windows below the shutters, &c.

Elevation. (Lat. Elevatio.) A geometrical projection drawn on a plane perpendicular to the horizon.

Ellipse or Ellipsis. (Gr. Ελλειψις, defect.) One of the conic sections produced by cutting a cone entirely through the curved surface, neither parallel to the base; nor making a subcontrary section, so that the ellipsis, like the circle, is a curve that returns into itself and completely encloses a space.

Ellipsograph. An instrument for describing an ellipsis by continued motion.

Ellipsoid. See Conoid.

Elliptic Arch. A portion of the curve of an ellipsis employed as an arch.

Elliptic Compasses. The same as Ellipsograph.

Elliptic winding Stairs. Such as are cased in and wind round an elliptic newel.

Elm. (Lat. Ulmus.) A forest tree occasionally used in building. See Book II. Chap. II. Sect. 4.

Elphage. See Architects, list of, 77.

Embankment. A term signifying any large mound of earth on the sides of a passage for water or other purposes; also for protection against the action of the sea. It is usually constructed of earth, and, when necessary to resist much force, cased with brick or stone.

Embattled. A wall indented with notches in the form of embrasures on the top of a wall, parapet, or other building. It is sometimes called *crenelle.*

Embattled Aronade. See Aronade.

Embattled-battled Line. A straight line bent into right angles, so that if there be three sets of parts one set may be parallel to the other two.

Embattled Buildings. Those with embrasures in the parapets, resembling a castle or fortified place.

Embossing or Embossed Work. (Fr. Bosse, a protuberance.) The raising or forming in relievo any sort of figure, whether performed with the chisel or otherwise. It is a kind of sculpture, in which the figures rise from the plane on which they are formed, and as they are more or less prominent they are said to be in *alto, mezzo,* or *basso relievo.*

Embrasure. An opening made in the wall or parapet of a fortified place. The term is also applied to an enlargement within of the sides of a window, in which sense it is the same as Splay, which see.

Emere, D'. See Architects, list of, 232.

Emplecton. (Gr. Εμπλεκω, I entangle.) Among the ancients, a method of constructing walls, in which, according to Vitruvius, the front stones were wrought fair and the interior left rough and filled in with stones of various sizes.

Encarpus. (Gr. Εν and καρπος.) The festoons on a frieze, consisting of fruit, flowers, leaves, &c.

End of a Stone. The two parallel sides which form the vertical joints.

Endecagon. (Gr. Ενδεκα, eleven, and Γωνια, an angle.) A plain geometrical figure bounded by eleven sides.

Engaged Columns. Those attached to walls, by which a portion of them is concealed. They never stand less than half their diameter out of the wall to which they are attached.

English Bond. See p. 515.

Ensemble. (Fr.) A term denoting the masses and details considered with relation to each other.

Entablature. (Fr. Entablement.) The whole of the parts of an order above a column. The assemblage is divided into three parts: the architrave, which rests immediately on the column; the frieze, next over the architrave, being the middle member; and the cornice, which is the uppermost part. The first and last are variously subdivided in the different orders. See the different orders, Book III. Chap. I.

Entasis. (Gr. Εντασις.) A delicate and almost imperceptible swelling of the shaft of a column, to be found in almost all the Grecian examples. It seems to have been adopted to prevent the crude appearance which the frusta of cones would have presented. This refinement is alluded to in the second chapter of the third book of Vitruvius, and was first in modern times observed in execution in 1814 by Mr. Allason.

Enter. (Verb.) In carpentry and joinery, the act of inserting the end of a tenon in the mouth of a mortise previous to its being driven home to the shoulder.

Entresol. (Fr.) A low story between two higher ones. See Mezzanine.

Envelope. (Verb.) The covering of a portion of the surface of a solid with a thin substance or wrapper, which in all points or parts comes in contact with the surface of such surface. To develop the surface of a solid is to find the envelopes that will cover its different parts.

Ephebeium. (Gr.) A building, in ancient architecture, for the exercise and wrestling of the youth.

Epicranitis. (Gr.) A name given by the Greeks to the tiles forming the cyma or upper member of the cornice of their temples.

Epicycloid. (Gr. Επικυκλος, and Ειδος, form.) In geometry, a curve line generated by the revolution of a point in the circumference of a circle, which rolls on the circumference of another circle, either externally or internally.

Episcenium. (Gr. Επι, upon, Σκηνη, a scene.) In ancient architecture, the upper order of the scene in a theatre.

Epistylium. Gr. Επι, upon, Στυλος, column.) The same as Architrave, which see.

Epitithedes. (Gr. Επι, upon, Τιθημι, I place.) The crown or upper mouldings of an entablature.

Equiangular. Having equal angles.

Equidistant. At equal distances.

Equilateral. Having equal sides.

Equilibrium. In mechanics, an equality of forces in opposite directions, so as mutually to balance each other. For the arch of equilibrium see Book II. Chap. I. Sect. 9.

Ergastulum. In ancient architecture, a name given by the Romans to a prison or house of correction, where slaves, by the sole authority of their masters, were confined for their offences and subjected to hard labour. By the Greeks these buildings were called *sophronisteria.*

Erwyn. See Architects, list of, 128.

Escobedo, D'. See Architects, list of, 197.

Esguerra. See Architects, list of, 225.

Estimate. (Substantive.) The computed cost of a building before the works are commenced. See Book II. Chap. III. Sect. 14.

Estrade. An even or level space; a public road.

Etienne de Bonneveil. See Architects, list of, 111.

Etruscan Architecture. See Book I. Chap. II. Sect. 12.

Eude de Montreuil. See Architects, list of, 117.

Eupalinus. See Architects, list of, 5.

Eupolemus. See Architects, list of, 27.

Eurithmy. (Gr. Ευρυθμια, justness of proportion.) The regular, just, and symmetrical measures resulting from harmony in the proportions of a building or order. Vitruvius makes it one of his six essentials.

Eustachius. See Architects, list of, 109.

Eustyle. (Gr. Ευ, well, and Στυλος, column.) See Colonnade.

Evaporation. (Lat.) The conversion of substances into vapour, during which process a considerable quantity of sensible heat passes into the *latent* or insensible state. The circumstances which principally influence the process of evaporation, are extent of surface, and the state of the air in respect of temperature, dryness, stillness, and density.

Eversden, D'. See Architects, list of, 136.

Eversolt. See Architects, list of, 103.

Evolute. (Lat. Evolvo.) In the theory of curve lines, is a curve from which any given curve may be supposed to be formed by the *evolution* or unlapping of a thread from a surface having the same curvature as the first curve. The curve thus generated is called the *involute curve.*

Excavation. (Lat.) As connected with architecture is the digging out or hollowing the ground for the foundations of a building, or of a floor below the level of the ground.

Exchange. See Book III. Chap. III. Sect. 14.

Exhedra. (Gr. Εξ, out of, and 'Εδρα, a chair.) In ancient architecture, a small room in the baths and other buildings appropriated for conversations.

Exostra. (Gr.) In ancient architecture, a machine for representing the interior part of a building as connected with the scene in a theatre.

Expansion. One of the ordinary effects of heat, which enlarges the bulk of all matter. Though the expansion of solids is by increase of temperature comparatively small, it may be rendered sensible by carefully measuring the dimensions of any substance when cold and again when heated. Thus an iron bar fitted to a gauge, showing its length and breadth, will, when heated, no longer pass through the apertures. The metals are most expansible by heat and cold. The following exhibits the change which some of them undergo when heated from the freezing to the boiling point of water: —

	Temperature.	
	32°	212°
Platinum	120000	120104.
Steel	—	120147.
Iron	—	120151.
Copper	—	120204.

	Temperature. 32°	 212°
Brass - - - -	120000	120230.
Tin - - - - -	—	120290.
Lead - - - - -	—	120345.
Zinc - - - - -	—	120360.

Extension. (Lat.) One of the general properties of matter, being the quantity of space which a body occupies, its extremities in every direction limiting or circumscribing the matter of that body. It is the magnitude, size, or bulk of a body.

External or Exterior. A term of relation applied to whatever is on the surface or outside of a body, as opposed to *internal* or *interior.*

Extrados. The exterior curve of an arch. The term is generally used to denote the upper curve of the *voussoirs* or stones which immediately form the arch.

Eye. A general term signifying the centre of any part: thus the *eye of a pediment* is a circular window in its centre. The *eye of a dome* is the horizontal aperture on its summit. The *eye of a volute* is the circle at the centre, from whose circumference the spiral line commences.

Eye, Bull's. See Bull's Eye.

Eyebrow. A name sometimes given to the fillet.

F.

Fabric. (Lat.) A general term applied to a large and important building.

Façade. (Fr.) The face or front of any building towards a street, court, garden, or other place; a term, however, more commonly used to signify the principal front.

Face Mould. The name applied by workmen to the pattern for marking the plank or board out of which ornamental hand-railings are to be cut for stairs or other works.

Face of a Stone. The surface intended for the front or outward side of the work. The back is usually left rough. Stones should be faced in the opposite direction of their splitting grain.

Facettes. (Fr.) Flat projections between the flutes of columns.

Facia or Fascia. (Lat. a Band.) A flat member of an order or of a building, like a flat band or broad fillet. The architrave, when subdivided for instance, has three bands called *fasciæ,* whereof the lower is called the first fascia, the middle one the second, and the upper one the third.

Facing. That part in the work of a building seen by a spectator; but the term is usually employed to signify a better sort of material, which masks the inferior one used internally.

Factabling. The same as Coping, which see.

Falconetto. See Architects, list of, 207.

Falling Moulds. The two moulds applied to the vertical sides of the railpiece, one to the convex, the other to the concave side, in order to form the back and under surface of the rail and finish the squaring.

False Attic. An attic without pilasters, casements, or balustrades, used for crowning a building, as at the gates St. Denis and St. Martin at Paris.

False Bearing. See Bearing Wall.

False Roof. That part between the ceiling of the upper floor and the covering of the roof.

Fanal. (Fr.) The French term for a lighthouse.

Fanum. (Lat.) A place consecrated to religion, including the building and ground belonging to it. Those temples erected to the memory of distinguished persons were called *fana* by the ancients.

Farlegh. See Architects, list of, 163.

Farm-houses. See Book III. Chap. III. Sect. 23.

Farraria. See Granary.

Fastigium. (Lat.) See Pediment.

Fathom. (Sax.) A measure of six feet, taken from the extent of both arms when stretched out in a right line. It is chiefly used in measuring the depth of water, quarries, wells, or pits.

Feather-edged. A term applied to any thin body whose section is trapezoidal; that is, thicker on one edge than on the other.

Feather-edged Boards. See Boards.

Feather-edged Coping. See Coping.

Feeder. A cut or channel by which a stream or supply of water is brought into a canal. Sometimes the supply itself of the water is so called.

Feeding House or Shed. A farm-building for stalling and fattening neat cattle. It should be in a dry warm situation, capable of free ventilation, and supplied with proper conveniences for food and water.

Felling Timber. The cutting down a full grown tree. Much difference of opinion has prevailed respecting the proper season for felling trees, some being in favour of midwinter and others of midsummer. It is however a question which principally turns upon the quantity and value of the soft or outer wood in the trunk of the tree to be felled, called *sap* by the forester and carpenter. This sap or outer wood being the only portion of the trunk in which the sap or juices of the tree circulate, if no value be set upon it, it seems of little consequence when the tree is cut down, because the mature timber, which is the really valuable part of the wood, is impermeable to the sap in its ascent through the soft wood, and is therefore in the same state at every season of the year. On the other hand, where much value attaches to the soft or outer wood, or where, as in the case of comparatively young trees, the greater part of the trunk consists of sap wood, they should be felled when the sap least circulates. The season in that case is doubtless midwinter, which, *cæteris paribus*, is certainly the best season for felling timber. The next best season seems to be midsummer, because the sap is then chiefly confined to the young shoots, to the circumference of the soft wood, and to the bark. The worst season would appear to be the spring, just before the development of the buds, when the tree is fullest of sap, and receiving fresh supplies of it from the root; and in autumn, immediately before the fall of the leaf, when there is a superabundance of sap, from its being as it were thrown out of employment by the falling of the leaf. In general all soft wood, such as elm, lime, poplar, willow, &c., should be felled during the winter. Hard woods, like the oak, beach, ash, &c., may be felled at any time, if the trunks are of large size, and chiefly valued for their heart-wood.

Felt Grain. That position of splitting timber which is cloven towards the centre of the tree, or transversely to the annular rings or plates. The transverse position, or rather that which is in the direction of the annular plates, is called the *quarter grain*.

Felting. The act of splitting timber by the felt grain.

Fence. (Lat. Defensio.) Any sort of construction for the purpose of enclosing land, as a bank of earth, a ditch, hedge, wall, railing, paling, &c.

Fender Piles. Those driven to protect work, either on land or in water, from the concussion of a moving body.

Festoon. (Fr.) A sculptured representation of flowers, drapery, and foliage, looped or suspended at intervals on walls. The festoon was much used on friezes, altars, tablets, also over or under niches, as well as in many other situations.

Fetching the Pump. The act of pouring water into the upper part of a pump to expel the air contained between the lower box or piston and the bottom of the pump.

Figure. In a general sense the terminating extremes or surface of a body. No body can exist without figure, or it would be infinite, and all space solid matter. Figure in geometry, any plane surface comprehended within a certain line or lines.

Filippo. See Architects, list of, 193.

Fillet. (Fr. Filet.) A narrow flat band, listel, or annulet used for the separation of one moulding from another, and to give breadth and firmness to the upper edge of a crowning moulding, as in a cornice. The small bands between the flutes of a column are called fillets. See Annulet and Band.

Fillet. In carpentry or joinery, is any small timber scantling equal to or less than battens. Fillets are used for supporting the ends of boards by nailing them to joists or quarters, &c., as in *sounding boarding*, and in supporting the ends of shelves.

Fillet Gutter. A sloping gutter, with a learboard and fillet thereon, to divert the water.

Filling in Pieces. In carpentry, short timbers, less than the full length, fitted against the hips of roofs, groins, braces of partitions, which interrupt the whole length.

Fine Stuff. Plaster used in common ceilings and walls for the reception of paper or colour. It is composed of lime slaked and sifted through a fine sieve, then mixed with a due quantity of hair and fine sand.

Finial. In Gothic architecture, the top or finishing of a pinnacle or gable, as it is now generally understood; but in ancient documents the term was used to denote an entire pinnacle.

Finishing. A term frequently applied to the termination of a building; but more especially to the interior in the plasterer's work for the last coat, and often to the joiner's work, as in the architraves, bases, surbases, &c.

Fioravanti. See Architects, list of, 159.

Fir. A forest tree, extensively used in building. See p. 484.

Fir Poles. Small trunks of fir trees, from ten to sixteen feet long, used in rustic buildings and outhouses.

Fir in Bond. A technical expression to denote lintels, bond timbers, wall plates, and all timbers built in walls. See Bond.

Fir wrought. That planed on the edges and sides.

Fir wrought and framed. That which is both planed and framed.

Fir wrought, framed, and rebated. That which is planed, framed, and rebated.

Fir wrought, framed, rebated, and beaded. The same as the preceding article, with the addition of beading.

Fir framed. Rough timber framed, but which has not undergone the action of planing.

Fir no Labour. Rough timber employed in walls, without planing or framing.

Fire-place. See Chimney.

Fire-stone. That which resists the action of the fire. A species of it is used in joinery for rubbing away the ridges made by the cutting-edge of the plane.

Firmer Tool. A tool used by joiners. See p. *565*.

First Coat. In plastering, the laying the plaster on the laths, or the rendering, as it is called, on brickwork, when only two coats are used. When three are used, it is called *pricking-up* when upon laths, and *roughing-in* when upon bricks.

Fischer, Von Erlach. See Architects, list of, 269.

Fischer, Carl. See Architects, list of, 313.

Fish. (Verb.) To secure a piece of wood by fastening another piece above or below it, and sometimes both, to strengthen it.

Fistuca. (Lat.) A pile-driving instrument with two handles raised by pulleys, and guided in its descent to fall on the head of a pile so as to drive it into the ground, being what is by the workmen called a *monkey*.

Fitz-Odo. See Architects, list of, 108.

Fixture. A term applied to all articles of a personal nature affixed to land. This annexation must be by the article being let into or united with the land, or with some substance previously connected therewith.

Flags. Thin stones used for paving, from one and a half to three inches thick, and of various lengths and breadths, according to the nature of the quarry.

Flake White. In painting, lead corroded by the pressing of grapes, or a ceruse prepared by the acid of grapes. It is of Italian manufacture, and for the purity of its white far surpasses the white lead of this country.

Flank. (Fr. Flanc.) That part of a return body which joins the front. In town houses the party-walls are the flank walls.

Flashing. (Probably from Fr. Flaque, a splash.) Pieces of lead or other metal let into the joints of a wall so as to lap over the gutters or other conduit pieces, and prevent the splashing of rain injuring the interior works.

Flat. That part of the covering of a house laid horizontal, and covered with lead or other material.

Flatting. In house painting, a mode of painting in oil, in which the surface is left, when finished, without any gloss. The material or paint is prepared with a mixture of oil of turpentine, which secures the colours, and when used in the finishing, leaves the paint quite dead. The process is of use where it is desirous that the surface painted should retain the colour. It is only used for inside work and in the best apartments. Nut oil may be used for the purpose, so may be poppy oil, both whereof are good media for the colour.

Flemish Bond. See p. *516*.

Flemish Bricks. A species of bricks used for paving, whereof seventy-two will pave a square yard; they were originally imported from Flanders, are of a yellowish colour, and harder than common bricks.

Flexibility. (Lat. Flecto.) That property of bodies which admits of their bending. It is opposed to *stiffness* on the one hand, and *brittleness* on the other; stiff bodies being such as resist bending, and brittle those which cannot be bent without a disruption of their parts.

Flexure. The bending or curve of a line or surface. The point of *contrary flexure* is that point of a curve where the curvature alters from convex to concave, or the reverse, as respects the first direction of the curve.

Flight of Steps. In a staircase is the series of steps from one landing place to another. Thus, the same staircase between one floor and another may consist of more than one flight of steps; the flight being reckoned from landing to landing.

Flint. A material often used in inferior building. Common flints are nearly pure *silica*. They usually occur in irregular nodules in chalk. Their origin is still an unsolved geological problem.

Float. In plastering, a long rule with a straight edge, by which the work is reduced to a plane surface.

Floated Lath and Plaster. Plastering of three coats, whereof the first is *pricking-up*, see Book II. Chap. III. Sect. 9.; the second, floating or floated work; and the last, of fine stuff.

Floated Work. Plastering rendered perfectly plane by means of a Float, which see.

Floating Screeds. (The etymon. of screeds, being probably schierato, ranged.) Strips of plaster previously set out on the work, at convenient intervals, for the *range* of the floating-rule or *float.*

Floor. (Sax. Flone.) The pavement or boarded lower horizontal surface of an apartment. It is constructed of earth, brick, stone, wood, or other materials. Carpenters include in the term the framed timber work on which the boarding is laid, as well as the boards themselves. In carpentry, it denotes the timbers which support the boarding, called also *naked flooring* (see p. 540.) and *carcass flooring*. The term floor is, moreover, applied to the stories of a building on the same level; thus, we have *basement floor*, *ground floor*, &c. When there is no sunk story, the ground story becomes the basement floor; the expressions, *one pair*, *two pair*, &c., implying a story above the first flight of stairs from the ground, and so on. The *principal floor* is that which contains the principal rooms; generally in country houses on the ground floor, but in those of the town mostly on the one pair floor.

Floor, folding or folded. One in which the floor boards are so laid that their joints do not appear continuous throughout the whole length of the floor, but in bays or folds of three, four, five, or more boards each.

Floor Joists are those which support the boards of the floor; but when the floor consists of binding and bridging joists, the bridgings are never called floor joists. For the better comprehension of the different sorts of floors in carpentry, see p. 540, *et seq.*

Floor straight Joint. That in which the floor boards are so laid that their joints or edges form a continued line throughout the direction of their length; in opposition to *folding floor*, wherein the joints end in *folds.*

Floors. See Book II. Chap. II. Sect. 4.

Florid Style. In Gothic architecture. See Book I. Chap. III. Sect. 5.

Flue. The long open tube of a chimney from the fire-place to the top of the shaft, for voidance of the smoke. See Chimney.

Fluing. The same as Splayed, which see.

Flush. (Lat. Fluxus.) A term used by workmen to signify a continuity of surface in two bodies joined together. Thus, in joinery, the style, rails, and munnions are usually made flush; that is, the wood of one piece on one side of the joint does not project or recede from that on the other.

Flush. In masonry or brick-work, the aptitude of two brittle bodies to splinter at the joints when the stones or bricks come in contact when contiguous in a wall.

Flush. (Verb.) A term to denote the complete bedding of masonry or brick-work, in the mortar or cement used for the connection of the stones or bricks, so as to leave no vacant space where the stones or bricks do not nicely fit in their places.

Flutes or Flutings. Upright channels on the shafts of columns, usually ending hemispherically at top and bottom. Their plan or horizontal section is sometimes circular or segmental, and sometimes, as in the Grecian examples, elliptical. The Doric column (see Book III. Chap. I. Sect. 4.) has twenty round its circumference; the Ionic, Corinthian, and Composite (see Sections 5, 6, and 7. of the same Chapter) have twenty-four. The Tuscan column is never fluted. Flutes are occasionally *cabled.* See Cable.

Flyers. Steps in a flight of stairs that are parallel to each other.

Flying Buttress. A buttress in the form of an arch, springing from a solid mass of masonry, and abutting against the springing of another arch which rises from the upper points of abutment of the first. It is employed in most of the cathedrals, and its office is to act as a counterpoise against the vaulting of the nave. If flying buttresses were built solid from the ground, it is obvious that they would interfere with the vista along the aisles of the church; hence the project of continuing a resistance by means of arches. Their stability depends on the resistance afforded by the weight of the vertical buttress, whence they spring. See Arc-boutant and Buttress.

Focus. In geometry and the conic sections, a point on the concave side of a curve, to which the rays are reflected from all points of such curve.

Fodder or Fother. A weight among the plumbers of London of 19¼ cwt.

Fœnilia. (Lat.) See Granary.

Foix, de. See Architects, list of, *245.*

Fold of a Floor. See Floor.

Folded Floor. See Floor.

Folding Doors. Such as are made to meet each other from the opposite jambs to which they are hung; and when they are rebated together, their edges meet folding over each other, with a bead at the joint, to give the appearance of one entire door.

Folding Joint. A.joint made like a rule-joint or the joint of a hinge.

Foliage. A sculptured group of the leaves of plants and flowers, so arranged as to form architectural ornaments, as in friezes, panels, &c., and in the capitals of the Corinthian and Composite orders.

Font. A vessel, generally of stone or water, for containing the water of baptism in the

Christian church. Some of the early fonts are extremely beautiful, and wrought with extraordinary richness of decoration. The singular inscription frequently found on the walls of baptisteries occurs also occasionally on ancient fonts: ΝΙΨΟΝ ΑΝΟΜΗΜΑΤΑ ΜΗ ΜΟΝΑΝ ΟΨΙΝ, which, reading equally well both ways, admonishes the reader to cleanse himself from sin, not less than to use the outward ceremony of baptism.

Fontana, Carlo. See Architects, list of, 266.

Fontana, Dom. See Architects, list of, 242.

Foot. (Germ. fuss.) A measure of length, but used also in a sense which expresses surface and solidity. Thus we say, a foot *superficial* and a foot *cube*. As this term is used in almost all languages as a linear measure, it has doubtless been derived from the length of the human foot. It seems in all other countries, as in England, to be divided into twelve equal parts, or inches.

The English standard foot (31 Edw. 1.) is = 12 lineal English inches = 36 barleycorns = 16 digits = 4 palms = 3 hands = 5⅓ nails = 1⅓ spans = 1·5151 Gunter's links = ·938306 ft. of France = ·3047 met. of France. The foot is divided by geometricians into 10 digits, and each digit into 10 lines, &c. The French, as the English, divide the foot into 12 inches, and the inch into 12 lines. The foot square or superficial is a foot each way, and contains, therefore, 12 × 12 = 144 superficial inches = 2·295684 square links. The glazier's foot in Scotland = 64 square Scotch inches.

The length of the foot varies in different countries. The Paris royal foot exceeds that of England by 9¼ lines. The ancient Roman foot of the Capitol consisted of 4 palms = 11 7/10 English inches. The Rhinland or Leyden foot, used by the northern nations of Europe, is to the Roman foot as 950 to 1000. The following table exhibits the length of the foot in the principal places of the Continent, the English foot being divided into 1000 parts, or 12 inches: —

Country.	Parts.	Ft.	In.	Lines.
London - - - - - -	1000	0	12	0
Amsterdam - - - - - -	942	0	11	2
Antwerp - - - - - -	946	0	11	3
Bologna - - - - - -	1204	1	2	4
Bremen - - - - - -	964	0	11	6
Cologne - - - - - -	954	0	11	4
Copenhagen - - - - - -	965	0	11	6
Dantzic - - - - - -	944	0	11	3
Dort - - - - - - -	1184	1	2	2
Frankfort-on-the-Maine - - - -	948	0	11	4
Lorrain - - - - - - -	958	0	11	5
Mantua - - - - - - -	1569	1	6	8
Mechlin - - - - - -	919	0	11	0
Middleburgh - - - - - -	991	0	11	9
Paris royal foot, according to Greaves - - -	1068	1	0	9·7
——— according to Bernard - - -	1066	1	0	1
——— according to Graham, from the measure of half the toise of the Chatelet, the toise being six Paris feet - - - - - -	1065·416			
——— according to Mounier - - -	1065·351			
——— from the two last - - -	1065·4	1	0	9·4
Prague - - - - - - -	1026	1	0	3
Rhinland or Leyden - - - - -	1033	1	0	4
Riga - - - - - - -	1831	1	9	9
Rome - - - - - - -	967	0	11	6
Strasburg - - - - - -	920	0	11	0
Spanish - - - - - - -	1001	1	0	0
Toledo - - - - - - -	899	0	10	7
Turin - - - - - - -	1062	1	0	7
Venice - - - - - - -	1162	1	1	9
Greek - - - - - - -	1007	1	0	1
Old Roman, according to Greaves - - -	967	0	11	6
——— from the monument of Statilius - - - - - -	972	0	11	7

Mr. Raper (*Philos. Trans.* vol. li.), from various authorities, determines the mean of the Roman foot to be nearly 968 parts of the London foot; and he considers that before the reign of Titus the Roman foot exceeded 970/1000 of the London foot, and afterwards, in the reigns of Severus and Diocletian, it fell short of 965. Cagnazzi, from examination of the monuments of antiquity in Herculaneum and Pompeii, determines the Roman foot at ·29624 metre, which, the metre being 3·2808992 English feet, would make the old Roman foot $\frac{972}{1000}$ of the English foot.

The Scotch is to the English foot as 1·066 to 1·000, being, in fact, the French foot. See **Measures.**

Foot of the Eye Director. In perspective, that point in the directing line made by a vertical plane passing through the eye and the centre of the picture.

Foot of a vertical Line. In perspective, that point in the intersecting line which is made by a vertical plane passing through the eye and the centre of the picture.

Foot Pace or Half Pace. That part of a staircase whereon, after the flight of a few steps, you arrive at a broad place on which you may take two or three paces before you come to another step. If it occur at the angle turns of the stairs, it is called a *quarter pace.*

Footing Beam. The name given, in some of the provinces, to the tie beam of a roof.

Footings of a Wall. Projecting courses of stone at the base of a wall or building to spread the base, and give it security.

Force. In mechanics, the course of motion in a body when it begins to move, or when it changes its direction from the course in which it was previously moving. While a body remains in the same state, whether of rest or of uniform and rectilinear motion, the cause of its so remaining is in the nature of the body, which principle has received the name of *inertia.* For the laws on the composition and resolution of forces, see p. 381, *et seq.*

Force Pump. See p. 584.

Forcer. In mechanics, a solid piston applied to pumps for the purpose of producing a constant stream, or of raising water to a greater height than it can be raised by the pressure of the atmosphere.

Fore Front. The principal or entrance front of a building.

Fore Plane. In carpentry and joinery, the first plane used after the saw or axe.

Foreshorten. In perspective, the diminution which the representation of the side or part of a body has, in one of its dimensions, compared with the other, occasioned by the obliquity of the corresponding side or part of the original body to the plane of projection.

Form. The external appearance or disposition of the surfaces of a body, in which sense it is synonymous with **Figure**, which see.

Forment. See **Architects**, list of, 221.

Forum. (Lat.) In ancient architecture, a public market; also a place where the common courts were held, and law pleadings carried on. The fora of the Romans were large open squares surrounded by porticoes, parts whereof answered for market-places, other parts for public meetings of the inhabitants, and other parts for courts of justice; the forum was also occasionally used for shows of gladiators. There were in Rome seventeen; of these fourteen were for the sale of goods, provisions, and merchandise, and called Fora Venalia; the other three were for civil and judicial proceedings, and called *Fora Civilia et Judicialia.* Of the latter sort was the forum of Trajan, of which the Trajan column formed the principal ornament.

Foundation. (Fr. Fondation.) The lower part of a wall on which an insistent wall is raised, than which, too, it is always much thicker. See Book II. Chap. III. Sect. 1.

Foundry. A building in which various metals are cast into moulds or shapes. See Book II. Chap. III. Sect. 11.

Fountain. (Lat. Fons.) Any natural or artificial apparatus by means whereof water springs up. In natural fountains the ascensional effect is produced by the hydrostatic pressure of the water itself; in artificial fountains, by the same sort of pressure, or by that of compressed air, and sometimes by machinery.

Fox Tail Wedging. A method of fixing a tenon in a mortise by splitting the end of the tenon and inserting a projecting wedge, then entering the tenon into the mortise, and driving it home. The bottom of the mortise resists the wedge, and forces it further into the tenon, which will expand in width, so as not only to fill the cavity at the bottom, but be firmly compressed by the sides of the mortise.

Frame and **Framing.** (Sax. Fꞃamman, to form.) The rough timber work of a house, including floors, roofs, partitions, ceilings, and beams. Generally, any pieces of wood fitted together with mortises and tenons are said to be framed, as doors, sash-frames, sashes, &c.

Franking. A term used by the makers of window-sashes, and applied to the mode of forming the joint when the cross-pieces of the frame intersect each other, no more wood being cut away than is sufficient to show a mitre.

Free Stone. Any stone which works freely, such as Portland stone, Bath stone, the limestones generally, &c.

Freeze. See **Frieze.**

French Architecture. See Book I. Chap. II. Sect. 17.

French Casements. Windows turning upon two vertical edges attached to the jambs, which, when shut, lap together upon the other two parallel edges, and are fastened by means of long bolts extending their whole height. French casements are made in the form of the old English window, the two meeting styles, which lap together, forming a munnion about 4 inches in breadth. The lower part only is moveable, the upper being fixed, and having a corresponding munnion: the lower rail of the fixed part and the upper rail of the moveable part forming a transom.

Fresco Painting. (It. Fresco, fresh.) A method of painting by incorporating the colours with plaster before it is dry, by which it becomes as permanent as the wall itself.

Frette or Fret. A species of ornament consisting of one or more small fillets meeting in vertical and horizontal directions. (See *fig.* 1044.) The sections of the channels between the fillets is rectangular.

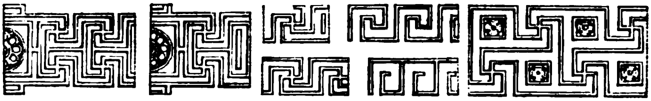


Fig. 1044.

Friction. (Lat. Frico, I rub.) The resistance produced by the rubbing of the surfaces of two solid bodies against each other.

Frieze, Freeze, or Frize. (Ital Fregio, adorned.) That member in the entablature of an order between the architrave and cornice. It is always plain in the Tuscan; ornamented with triglyphs and sculpture in the Doric; in the modern or Italian Ionic it is often swelled, in which case it is said to be *pulvinated* or *cushioned;* and in the Corinthian and Composite it is variously decorated, according to the taste of the architect.

Frieze of the Capital. The same as the Hypotrachelium, which see.

Frieze Panel. The upper panel of a six-panelled door.

Frieze Rail. The upper rail but one of a six-panelled door.

Frigidarium. In ancient architecture, the apartment in which the cold bath was placed. The word is sometimes used to denote the cold bath itself.

Frize or Frise. See Frieze.

Front. (Lat. Frons.) Any side or face of a building, but more commonly used to denote the entrance side.

Frontinus. See Architects, list of, 46.

Frontispiece. (Lat. Frons and Inspicio.) The face or fore-front of a house, but the term is more usually applied to the decorated entrance of a building.

Fronton. The French term for a pediment.

Frosted. A species of rustic-work, imitative of ice, formed by irregular drops of water.

Frowcester. See Architects, list of, 150.

Frowey Timber. Such as works freely to the plane without tearing, whose grain therefore is in the same direction.

Frustum. (Lat.) In geometry, the part of a solid next the base, formed by cutting off the top, or it is the part of any solid, as a cone, a pyramid, &c., between two planes, which may be either parallel or inclined to each other.

Fuccio. See Architects, list of 122.

Fuga. See Architects, list of, 295.

Fulcrum. (Lat.) In mechanics, the fixed point about which a lever moves.

Funnel. (Lat. Infundibulum.) That part of a chimney contained between the fire-place and the summit of the shaft. See Chimney.

Furnace. (Lat. Fornax.) An apparatus wherein is formed a cavity to contain combustible matter, which in various ways is supplied with air, to facilitate its combustion. The two classes into which furnaces are divided are air or wind furnaces and blast furnaces. In the former, the air is conducted through the fire by the draught of a funnel or chimney communicating with it; in the latter, the action of bellows, or some other pneumatic apparatus, supplies the air. The word furnace has generally, however, a more circumscribed application, being applied usually to an apparatus for the fusion of metals, or to that used in a chemical laboratory.

Furniture. (Fr. Fournir, to furnish.) The visible brass work of locks, knobs to doors, window-shutters, and the like.

Furring. (Fr. Fourrir, to thrust in.) The fixing of thin scantlings or laths upon the edges of any number of timbers in a range, when such timbers are out of the surface they were intended to form, either from their gravity, or in consequence of an original deficiency of the timbers in their depth. Thus the timbers of a floor, though level at first, oftentimes require to be furred; the same operation is frequently necessary in the reparation of old roofs, and the same work is required sometimes in new as well as old floors.

Furrings. The pieces of timber employed in bringing any piece of work in carpentry to a regular surface when the work is uneven, either through the sagging of the timber or other causes.

Fusarole. (It.) A member whose section is that of a semicircle carved into beads. It is generally placed under the echinus, or quarter round of columns in the Doric, Ionic, and Corinthian orders.

Fussitius. See Architects, list of, 39.

Fust. (Fr. Fût.) The shaft of a column or trunk of a pilaster.

Fust. A term used in Devonshire, and, perhaps, in some other counties, to signify the ridge of a house.

G.

Gable. (Brit. Gavel.) The vertical triangular piece of wall at the end of a roof, from the level of the eaves to the summit.

Gabriel, J. A. See Architects, list of, 297.

Gabriel, Jacques. See Architects, list of, 277.

Gage, or Gauge. (Sax. Ᵹæᵹᵹian, to bind or confine.) In carpentry or joinery, an instrument for drawing one or more lines on any side of a piece of stuff parallel to one of the arrisses of that side. Of this tool there are four sorts; the common gage and the flooring gage (which are both applied to the drawing of a line parallel to an arris), the internal gage, and the mortise and tenon gage.

This term is also used to signify the length of a slate or tile below the lap; also the measure to which any substance is confined. It is, moreover, used by plasterers to signify a greater or less quantity of plaster of Paris used with common plaster to accelerate its setting.

Gain. In carpentry, the bevelled shoulder of a binding joist, for the purpose of giving additional resistance to the tenon below.

Gainsborough. See Architects, list of, 145.

Gainza. See Architects, list of, 222.

Galilee. A porch usually built near the west end of abbey churches, where the monks collected in returning from processions, where bodies were laid previous to interment, and where females were allowed to see the monks to whom they were related, or to hear divine service. The galilees of Durham and Ely are found in the situation here described. The former is highly ornamented, and is eighty by fifty feet, and divided into five aisles by clustered columns and semicircular arches. The date of its erection was towards the end of the twelfth century. That of Ely Cathedral is much smaller. It is still used as the principal entrance to the church, and is without columns or other internal support. The porch at the south end of the great transept at Lincoln Cathedral is also sometimes called a galilee. The word has been frequently used, but improperly, to designate the nave of a church. Many conjectures have been made on the origin of this term, but the most commonly received opinion, founded on a passage in the writings of St. Gervase of Canterbury, is, that when a female applied to see a monk, she was directed to the porch of the church, and answered in the words of Scripture, "He goeth before you into Galilee, there shall you see him."

Galilei. See Architects, list of, 275.

Gallery. (Fr. Galerie.) An apartment of a house, for different purposes. A common passage to several rooms in any upper story is called a gallery. A long room for the reception of pictures is called a picture gallery. The platform on piers, or projecting from the wall of a church and open in front to the central space is also called a gallery. The Whispering Gallery at St. Paul's is another example of the various uses of the word. The whole or a portion of the uppermost story of a theatre is likewise called a gallery. The term is, moreover, used to denote porticoes formed with long ranges of columns on one side.

Galli. See Architects, list of, 276.

Gandon. See Architects, list of, 315.

Gaol. A prison, or place of legal confinement. See Book III. Chap. III. Sect. 18.

Garden Sheds. Erections for containing garden implements, flower-pots, hot-bed frames, and glass sashes, &c.; also for working in during bad weather. They are best placed on the back wall of the tool-house, and thus hold the furnaces, fuel, and other articles.

Garlands. (Fr.) Ornaments of flowers, fruit, and leaves anciently used at the gates of temples where feasts or solemn rejoicings were held.

Garnets, Cross. A species of hinge used in the most common works, formed in the shape of the letter T turned thus ⊢, the vertical part being fastened to the style or jamb of the doorcase, and the horizontal part to the door or shutter.

Garret. The upper story of a house taken either partially or wholly from the space within the roof.

Garzia. See Architects, list of, 232.

Gate. (Sax. Ᵹeat.) A large door, generally framed of wood. The width of gates should be from eight and a half to nine feet, and the height from five to eight feet. The materials of gates should be well seasoned previous to use, otherwise they will be soon injured by the sun and wind. The parts should be also very correctly put together. For durability, oak is the best; but some of the lighter woods, as deal, willow, and alder, are, on account of their lightness, occasionally used. These, however, are more for field-bar gates than close gates.

Gauge. See Gage.

Gavel. The same as Gable, which see.

Gathering of the Wings. See Chimney.

Generating Curve. See Evolute.

Generating Line or Plane. In geometry, a line or plane which moves according to a given law, either round one of its extremities as a fixed point or axis, or parallel to itself, in order to generate a plane figure, or solid, formed by the space it has gone over.

Genesis. (Gr.) In geometry, the formation of a line, plane, or solid, by the motion of a point, line, or plane. See Generating Line.

Genga. See Architects, list of, 212.

Geometrical. That which has a relation to geometry.

Geometrical Staircase. That in which the flight of stairs is supported by the wall at one end of the steps.

Geometry. (Gr. Γη, the earth, and Μετρω, I measure.) That science which treats of the objects of figured space. Its etymology implies the object of measuring land, that, as it is said, being its first application in Egypt, where it is pretended to have been invented, for ascertaining the landmarks after the yearly recession of the inundations of the Nile, in order to mark the proper allotment of each owner. Whatever the origin, however, of the term, the occasions on which it is necessary to compare things with one another in respect of their forms and magnitudes are so numerous in every stage of society, that a geometry more or less perfect must have existed from the first periods of civilisation. See Book II. Chap. I. Sect. 2.

Geometry, descriptive. The art of representing a definite body upon two planes at right angles with each other, by lines falling perpendicularly to the planes from all the points of concourse of every two contiguous sides of the body, and from all points of its contour, and, *vice versâ*, from a given representation to ascertain the parts of the original objects. See Book II. Chap. I. Sect. 6.

Geometry, practical. See Book. II. Chap. I. Sect. 3.

Germain, St. See Architects, list of, 57.

Gibbs, J. See Architects, list of, 281.

Gibbs, W. See Architects, list of, 188.

Giblea Cheque. A term used by Scotch masons to denote the cutting away of the right angle formed by the front and returns of the aperture of a stone door-case, in the form of a rebate or reveal, so as to make the outer side of the door or closure flush with the face of the wall.

Gilding. The practice of laying gold leaf on any surface. See Book II. Chap. III. Sect. 12.

Gill. A measure equal to one fourth of a pint.

Gimbals, Gimbols, or Gimbles. (Lat. Gemellus.) A piece of mechanism consisting of two brass hoops or rings which move within one another, each perpendicularly to its plane, about two axes at right angles to each other. A body suspended in this manner, having a free motion in two directions at right angles, assumes a constantly vertical position.

Gimlet, or perhaps more properly **Gimblet.** (Fr. Guimbelet.) A piece of steel of a semi-cylindrical form, hollow on one side, having a cross handle at one end and a worm or screw at the other. Its use is to bore a hole in a piece of wood. The screw draws the instrument into the wood when turned by the handle, and the excavated part, forming a sharp angle with the exterior, cuts the fibres across, and contains the core of the wood cut out.

Giocondo. See Architects, list of, 182.

Giorgio, Di. See Architects, list of, 161.

Giovan Baptista di Toledo. See Architects, list of, 234.

Giovanni da Pisa. See Architects, list of, 129.

Girder. (Sax. Ᵹẏꞃdan, to enclose.) The principal beam in a floor, for supporting the binding or other joists, whereby the bearing or length is lessened. Perhaps so called because the ends of the joists are enclosed by it.

Girdle. A circular band or fillet surrounding a part of a column.

Girt. The length of the circumference of an object, whether rectilinear or curvilinear, on its horizontal section. In timber measuring, according to some, is taken at one fourth of the circumference of the tree, and is so taken for the side of a square equal in area to the section of the tree cut through, where the perimeter is taken in order to obtain the girt.

Glass. (Germ.) A transparent, impermeable, and brittle substance, whereof the different sorts used in building are described, Book II. Chap. II. Sect. 11.

Glass Painting. A decoration frequently used in buildings, is the method of staining glass in such a manner as to produce the effect of representing all the subjects whereof the art is susceptible. A French painter of Marseilles is said to have been the first who instructed the Italians in this art, during the pontificate of Julius II. . It was, however, practised to a considerable extent by Lucas of Leyden and Albert Durer. The different colours are prepared as follows: —*Black* is produced by two thirds of iron scales or flakes, and the other third of small glass beads, or a substance called *roccaglio* by the Italians. *White* is prepared for by sand or small white pebbles calcined, pounded, and then finely ground. One fourth part of saltpetre is added, and the mixture is then again calcined and pulverised, to which a little gypsum or plaster of Paris is added. *Yellow* is formed from leaf silver, ground and mixed in a crucible with saltpetre or sulphur; then ground on a porphyry stone, and lastly, again ground with nine times the quantity of red ochre. *Red*, one of the most difficult of the colours to make, is prepared from litharge of silver and iron scales, gum Arabic, ferretta, glass beads, and bloodstone, in nearly equal quantities. Great experience is necessary to succeed in making this colour. *Green* is produced from os ustum one ounce, the same quantity of black lead, and four ounces of white lead, incorporated by the action of fire. When calcined, a fourth part of saltpetre is added, and, after a second calcination, a sixth more; after which a third coction is made before using it. *Azure, purple*, and *violet* are prepared in a similar manner to green, omitting the os ustum, and in its stead using sulphur for azure, perigueux for purple, and both these drugs for violet. *Carnations*, which are compounded colours, are calcined, and usually mixed with water. They must be finished part by part, and each with great dispatch, before the plaster dries, for there is little opportunity for blending. The lights cannot be heightened, but the shadows may, when they begin to dry, be a little strengthened. Promptitude and facility in execution are the great requisites for this method of painting.

Glass Plate. Glass cast in plates and polished. See p. 510. The following is the tariff of the Thames Plate Glass Company, Savoy Wharf, London, for unsilvered plates, from one to seventy-five feet superficial: —

Feet Super.	£	s.	d.	Feet Super.	£	s.	d.	Feet Super.	£	s.	d.
1	0	8	9	26	26	4	4	51	72	0	9
2	1	0	0	27	27	15	9	52	74	2	0
3	1	13	9	28	29	5	8	53	76	8	2
4	2	5	0	29	30	18	8	54	78	10	6
5	2	16	3	30	32	10	0	55	80	13	4
6	3	7	6	31	34	7	7	56	82	16	8
7	3	18	9	32	35	17	4	57	85	5	3
8	4	10	0	33	37	8	0	58	87	9	8
9	5	6	6	34	39	2	0	59	89	14	7
10	6	5	0	35	40	19	7	60	91	15	0
11	7	3	11	36	42	15	0	61	94	5	11
12	8	5	0	37	44	11	1	62	96	12	4
13	9	5	3	38	46	4	8	63	98	19	3
14	10	6	6	39	48	2	0	64	101	6	8
15	11	10	0	40	50	0	0	65	103	9	2
16	12	13	4	41	51	18	8	66	106	3	0
17	13	17	8	42	53	14	6	67	108	11	11
18	15	1	6	43	55	14	5	68	110	15	8
19	16	7	9	44	57	15	0	69	113	5	6
20	17	13	4	45	59	16	3	70	115	15	10
21	18	19	9	46	61	14	4	71	118	4	0
22	20	7	0	47	63	16	10	72	120	16	0
23	21	15	1	48	65	16	0	73	123	4	0
24	23	4	0	49	67	15	8	74	125	16	0
25	24	13	9	50	70	0	0	75	128	8	0

The cost of silvering is about 20 to 25 per cent. on the above prices.

Glazier. An artisan whose employment is that of fitting and fixing the glass employed in a building. See Book II. Chap. III. Sect. 8.

Glue (from the Lat. Gluten.) A tenacious viscid matter made of the skins and hoofs of animals, for cementing two bodies together. Glue is bought in cakes, and is better the older the skin of the animal from which it is made. That which swells without dissolving when steeped in water is the best. To prepare glue it should be broken into small fragments and then steeped in water about twelve hours. It should be then heated in a leaden or copper vessel till the whole is dissolved, stirring it frequently with a stick. After this it is put into a wooden vessel and remains for use. Good glue for external work is made by grinding as much white lead with linseed oil as will just make the liquid of a whitish colour, and strong but not thick.

Glyph. (Gr. Γλυφω, I carve.) A sunken channel, the term being usually employed in reference to a vertical one. From their number, those in the Doric order are called triglyphs.

Glyptotheca. (Gr. Γλυφω, and Θηκη, deposit.) A building or room for the preservation of works of sculpture.

Gneiss. A species of granite which, from excess of mica, is generally of a lamellar or slaty texture. It is a term used by the miners of Germany.

Gnomon. (Gr. Γνωμων.) An instrument for measuring shadows, and thereby determining the sun's height. In dialling, it is the style of the dial, and its shadow marks the hour. It is placed so that its straight edge is parallel to the axis of the earth's rotation. In geometry, a gnomon is that part of a parallelogram which remains when one of the parallelograms about its diagonal is removed; or the portion of the parallelogram composed of the two complements and one of the parallelograms about the diagonal. The term is found in Euclid, but is now rarely used.

Gocciolatoio. The same as Corona, which see.

Gola, or Gula. (It.) The same as Cyma, which see.

Goldcliff. See Architects, list of, 102.

Gondouin. See Architects, list of, 312.

Goniometer. (Gr. Γωνια, an angle, and Μετρω, I measure.) An instrument for measuring solid angles.

Gonsalvo. See Architects, list of, 118.

Gorge. The same as Cavetto, which see. The *gorgerin* is a diminutive of the term.

Gorgoneia. (Gr.) Key-stones carved with Gorgons' heads.

Gothic Architecture. See Book I. Chap. II. Sect. 15.; and same Book, Chap. III. Sections 2, 3, 4, and 5.

Goufing Foundations. A Scotch term, signifying a mode of securing unsound walls by driving wedges or pins under their foundations.

Gouge. A chisel whose section is of a semicircular form.

Government Offices. See Book III. Chap. III. Sect. 5.

Gradetti. The same as Annulets, which see.

Græcostasis. A hall or portico adjoining the Roman comitia, in which foreign ambassadors waited before entering the senate, and also whilst waiting the answer that was to be given to them.

Grain. In wood or stone, is the line of direction in which either may be split transversely.

Granary. (Lat. Granum.) A building for storing corn, especially that intended to be kept for a considerable time. Vitruvius calls those buildings intended for the preservation of grain, *granaria*, those for hay *fœnilia*, and those for straw *farraria*. The term *horreum* was used by the Romans for denoting buildings not only for the preservation of corn, but for various other effects.

Grand. A term used in the fine arts, generally to express that quality by which the highest degree of majesty and dignity is imparted to a work of art. Its source is, in form, freed from ordinary and common bounds, and to be properly appreciated requires an investigation of the different qualities by which great and extraordinary objects produce impressions on the mind.

Grange. A farm-yard or farmery, consisting of a farm-house and a court of offices for the different animals and implements used in farming, as also of barns, feeding houses, poultry houses, &c.

Granite. See Book II. Chap. II. Sect. 2.

Graticulation. The division of a design or draught into squares, for the purpose of reducing it to smaller dimensions.

Gravel. A term applied to a well-known material of small stones, varying in size from a pea to a walnut, or something larger. It is often intermixed with other substances, as sand, clay, loam, flints, pebbles, iron ore, &c.

Gravity. See Specific Gravity.

Grecian Architecture. See Book I. Chap. II. Sect. 11.

Greek Cross. See Cross.

Greek Masonry. The manner of bonding walls among the Grecians. See Masonry.

Greenhouse. A building for sheltering in pots plants which are too tender to endure the open air the greater part of the year. It is constructed with a roof and one or more sides of glass, and being one constructed for luxury should not be far away from the dwelling-house, so that the greatest enjoyment may be had from it. At the same time it should, if possible, be near the flower-garden, as being of similar character in use. The length and breadth can only be determined by the wealth and objects of the proprietor. The best aspects are south and south east, but any aspect may, in case of necessity, be taken, if the roof be entirely of glass, and plenty of artificial heat be supplied. In those greenhouses, however, which face the north, the tender plants do not in winter succeed so well, and a greater quantity of artificial heat must then be supplied, and the plants should, in such case, be chiefly evergreens, and others that come into flower in the summer season, and grow and flower but little during the winter. The plants in greenhouses are kept in pots or boxes on stages or shelves, so as to be near and follow the slope of the roof, and thus made more susceptible of the action of the sun's rays immediately on passing through the glass.

An orangery, from being constructed with a ceiled roof, differs from a greenhouse; it is, moreover, chiefly devoted to plants producing their shoots and flowers in the summer season, and in the open air; the use of the orangery being merely to preserve them during the winter. The structure is more properly called a conservatory, though this term is now applied to buildings with glass roofs, wherein the plants are not kept in pots, but planted in the free soil, and wherein some are so reared as to grow and flower in the winter months.

Grey Stocks. Bricks of the third quality of the best or malm bricks. See Book II. Chap. II. Sect. 10.

Grinding. The act of taking off the redundant parts of a body, and forming it to its destined surface.

Grindstone. A cylindrical stone, mounted on a spindle through its axis, with a winch-handle for turning it, to grind edge-tools.

Grit Stone. One of various degrees of hardness; mostly of a grey, sometimes of a yellowish, colour. It is composed of a siliceous and micaceous sand, closely compacted by an argillaceous cement. It gives some sparks with steel, is indissoluble, or nearly so, in acids, and vitrifiable in a strong fire. It is used for millstones more than for building.

Groin. (Sax. Ᵹꞃoƿꞇn, to grow.) The line formed by the intersection of two arches, which cross each other at any angle. See Cross Vaulting, and Book II. Chap. I. Sect. 9.

Groined Ceiling. One formed by three or more curved surfaces, so that every two may form a groin, all the groins terminating at one extremity in a common point.

Groove. (Sax. Ᵹꞃaꝼan, to dig.) A sunken rectangular channel. It is usually employed to connect two pieces of wood together, the piece not grooved having on its edge a projection or *tongue*, whose section corresponds to and fits the groove.

Grotesque. (Fr.) A term applied to capricious ornaments which, as a whole, have no type in nature, consisting of figures, animals, leaves, flowers, fruits, and the like, all connected together.

Ground Joists. Those which rest upon sleepers laid upon the ground, or on bricks, prop stones, or dwarf walls; they are only used in basement and ground floors.

Ground Line. In perspective, the intersection of the picture with the ground plane. See Ground Plane.

Ground Niche. One whose base or seat is on a level with the ground floor.

Ground Plan. The plan of the story of a house level with the surface of the ground, or a few steps above it. It is not always the lowest floor, the basement being frequently beneath it.

Ground Plane. In perspective the situation of the original plane in the supposed level of our horizon. It differs from the horizontal plane, which is said of any plane parallel to the horizon; whereas the ground plane is a tangent plane to the surface of the earth, and is supposed to contain the objects to be represented. The term *ground* plane is used in a more confined sense than that of original plane, which may be any plane, whether horizontal or inclined.

Ground Plate or Ground Sill. The lowest horizontal timber on which the exterior walls of a building are erected. It chiefly occurs in timber buildings, or in buildings whose outside walls are formed of brick panels with timber framings.

Ground Plot. The plan of the walls of a building where they first commence above the foundation, though more properly it is the piece of ground selected to receive the building. For dwellings, its chief requisites are a healthy situation, a convenient supply of water, good drainage, a pleasant aspect, &c. If for trade or manufacture, it should be conveniently placed for receiving the raw material, and for exporting the articles manufactured.

Grounds. In joinery, certain pieces of wood attached to a wall, to which the finishings are fastened. Their surface is flush with the plastering. Narrow grounds are those whereto the bases and surbases of rooms are fastened. Grounds are used over apertures, as well for securing the architraves as for strengthening the plaster. That the plaster may be kept firm, should the wood shrink, a groove is sometimes run on the edge of the ground next to the plaster, or the edge of the ground is rebated on the side next to the wall, so that in the act of plastering the stuff is received into the groove or rebate, which prevents it from shifting when it becomes dry.

Grouped Columns or Pilasters. A term used to denote three, four, or more columns placed upon the same pedestals. When two only are placed together they are said to be coupled.

Grout. (Sax. Ᵹꞃuꞇ.) A thin semi-liquid mortar, composed of quicklime and fine sand, prepared and poured into the joints of masonry and brickwork, which process is called *grouting*.

Growing Shore. See Dead Shore.

Gudgeon. The axle of a wheel, on which it turns and is supported. To diminish friction gudgeons are made as small as possible in diameter, consistent with their weight. They are often made of cast iron, on account of its cheapness, but wrought iron of the same dimensions is stronger, and will support a greater load.

Gueule. A term synonymous with Cymatium.

Guilloche. (Fr.) An ornament in the form of two or more bands or strings twisting over each other, so as to repeat the same figure, in a continued series, by the spiral returning of the bands. The term is applied but improperly to Frets, which see.

Gula. Synonymous with Cymatium, which see.

Gulielmo. See Architects, list of, 99.

Gundulph. See Architects, list of, 87.

Gunter's Chain. One used for measuring land, and taking its name from its reputed inventor. It is 66 feet, or 4 poles, long, and divided into 100 links, each whereof is joined to the adjacent one by three rings; the length of each link, including the adjacent rings, is therefore 7·92 inches. The advantage of the measure is in the facility it affords to numerical calculation. Thus the English acre, containing 4840 yards, and Gunter's chain being 22 yards long, it follows that a square chain is exactly the tenth part of an acre, consequently the contents of a field being cast up in square links, it is only necessary to divide by 100,000, or to cut off the last five figures, to obtain the contents expressed in acres.

Guttæ. See Drops.

Gutters and Guttering. Canals to the roofs of houses to receive and carry off rainwater. They are made either of lead or of tiles, which are either plain or concave; these last are called gutter tiles, and so adapted to each other as to be laid with great ease. The Romans had gutters of terra cotta along the roofs of their houses, and the rain-water from them ran out through the heads of animals and other devices placed in the angles and in convenient parts. Leaden gutters were known in the middle ages.

Gymnasium. (Gr. Γυμνασιον, from Γυμνος, naked.) Originally a space measured out and covered with sand for the exercise of athletic games. The gymnasia in the end became spacious buildings, or institutions, for the mental as well as corporeal instruction of youth. They were first erected at Lacedæmon, whence they spread, through the rest of Greece, into Italy. They did not consist of single edifices, but comprised several buildings and porticoes for study and discourse, for baths, anointing rooms, palæstras, in which the exercises took place, and for other purposes.

Gynæceum. (Gr. Γυνακειον.) In ancient architecture, that portion of the Grecian house set apart for the occupation of the female part of the family.

Gypsum. (Probably from Γη, earth, and Εψω, I concoct.) Crystals of native sulphate of lime. Being subjected to a moderate heat, to expel the water of crystallisation, it forms plaster of Paris, and, coming in contact with water, immediately assumes a solid form. Of the numerous species, alabaster is, perhaps, the most abundant.

H.

Hacks. In brickmaking (see p. 503.) the rows in which bricks are laid to dry after being moulded.

Hacking. In walling, denotes the interruption of a course of stones, by the introduction of another on a different level, for want of stones to complete the thickness. Thus making two courses at the end of a wall of the same height as one at the other. The last stone laid is often notched to receive the first stone of the other where the two heights commence. Hacking is never permitted in good work. The term is used more in Scotland than in England.

Half Pace. See Foot Pace.

Half Round. A semicircular moulding, which may be a bead or torus.

Hall. (Sax. Hal.) A name applied indifferently to the first large apartment on entering a house, to the public room of a corporate body, a court of justice, or to a manor house.

Vitruvius mentions three sorts of halls: the Tetrastyle, which has four columns supporting the ceiling; the Corinthian, which has engaged columns all round, and is vaulted; and the Egyptian, which has a peristyle of insulated Corinthian columns, bearing a second order with a ceiling. These were called *œci*. In magnificent edifices, where the hall is larger and loftier than ordinary, and is placed in the middle of the house, it is called a saloon; and a royal apartment consists of a hall or chamber of guards, a chamber, an anti-chamber, a cabinet chamber, and a gallery.

Halving. A method of joining timbers by letting them into each other. It is preferable to mortising, even where the timbers do not pass each other, as they are less liable to be displaced by shrinking.

Ham. (Sax.) Properly a house or dwelling place; also a street or village, whence it has become the final syllable to many of our towns, as Notting*ham*, Bucking*ham*, &c.; hence, too, *hamlet*, the diminutive of *ham*, is a small street or village.

Hammer Beam. A beam acting as a tie at the feet of a pair of principal rafters, but not extending so as to connect the opposite sides. Hammer beams are used chiefly in roofs constructed after the Gothic style, the end which hangs over, being frequently supported by a concave rib springing from the wall, as a tangent from a curve, and in its turn supporting another rib, forming an arch. The ends of hammer beams are often decorated with beads and other devices.

Hand-rail of a Stair. A rail raised upon slender posts, called balusters, to prevent persons falling down the well hole, as also to assist them in ascending and descending.

Handspike. A lever for raising a weight, usually of wood, and applied to the holes in a capstan head.

Hang over. (Verb.) A term used to denote the condition of a wall when the top projects beyond the bottom.

Hangings. Linings for rooms of arras, tapestry, paper, or the like. Paper hangings were introduced early in the seventeenth century.

Hanging Stile of a Door. That to which the hinges are attached.

Harlewin. See Architects, list of, 85.

Harmonical Proportion. That which, in a series of quantities, any three adjoining terms being taken, the difference between the first and second is to the difference between the second and third, as the first is to the third.

Harmus. (Gr. 'Αρμος.) In ancient architecture, a tile used for covering the joint between two common tiles.

Harness Room. A room wherein harness is deposited. It is absolutely requisite that it be dry and kept clean. Its situation should be near the stable it is destined to serve.

Hassack. The provincial name for Kentish rag stone.

Hatchet. (Fr. Hachette.) A small axe used by joiners for reducing the edges of boards.

Haunches of an Arch. The parts between the crown and the springing.

Hawk. A small quadrangular tool with a handle, used by a plasterer, on which the stuff required by him is served, for his proceeding with the work in progress. He has always a boy attendant on him, by whom he is supplied with the material. The boy in question is called a *Hawk-boy*.

Hawksmoor. See Architects, list of, 273.

Head. See Aperture.

Head Jerkin. See Jerkin.

Headers. In masonry, stones extending over the thickness of a wall; and in bricklaying, the bricks which are laid lengthwise across the thickness of the wall are called *headers*.

Heading Course. In brickwork and masonry, that in which the length of the stone or brick is across the thickness of the wall.

Heading Joint. In joinery, the joint of two or more boards at right angles to the fibres, or in handrailing at right angles to the back; this is so disposed with a view of continuing the length of the board when too short. In good work the heading joints are ploughed and tongued, and in dadoes are, moreover, connected with glue

Headway of Stairs. The clear distance, measured perpendicularly, from a given landing-place or stair to the ceiling above, allowing for the thickness of the steps.

Headwork. A name by which the heads and other ornaments on the keystones of arches is frequently designated.

Heart Bond. In masonry, that in which two stones of a wall forming its breadth, have one stone of the same breadth placed over them. See Bond.

Hearth. See Chimney.

Heather Roof. A covering used in Scotland, by some considered superior to straw.

Hebrew Architecture. See Book I. Chap. II. Sect. 6.

Hecatompedon. (Gr.) A temple of a hundred feet in length. As applied to the Parthenon, for discovering the true length of the Greek foot. Stuart took considerable pains in the measurement of that temple. The results, as published by Revely, are as follow: —

	Eng. Inches.
Length of the upper step, in front of the temple, gives for one foot	12·139
From outside to outside of the angular columns	12·095
From centre to centre of the front columns	12·0982
Length of the architrave	12·0625

Heek. The same as Rack.

Heel. A term used by workmen to denote a *cyma reversa*.

Heel of a Rafter. The end or foot that rests on the wall plate.

Height. The perpendicular distance of the most remote part of a body from the plane on which it rests.

Height of an Arch. A line drawn from the middle of the chord or span to the intrados.

Helical Line of a Handrail. The spiral line twisting round the cylinder, representing the form of the handrail before it is moulded.

Heliocaminus. (Gr. 'Ηλιος, the sun, and Καμινος, a furnace.) A chamber in the Roman houses which depended on the rays of the sun for warming it.

Helix. (Gr. ῞Ηλιξ, a kind of ivy whose stalk curls.) A small volute or twist under the abacus of the Corinthian capital, in which there are, in every perfect capital, sixteen, called also *urillæ;* viz. two at each angle, and two meeting under the middle of the abacus, branching out of the caulicoli or stalks, which rise from between the leaves.

Helpstone. See Architects, list of, 135.

Hem. The spiral projecting part of the Ionic capital.

Hemicycle. A semicircle; the term is used architecturally to denote vaults of the cradle form, and arches or sweeps of vaults, constituting a semicircle.

Hemisphere. In geometry, the half of a globe or sphere, when divided by a plane passing through its centre.

Hemitriglyph. A half triglyph.

Henry of Blois. See Architects, list of, 92.

Henry Latomus. See Architects, list of, 134.

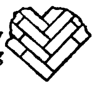
Heptagon. (Gr.) A geometrical figure of seven sides and angles.

Hermitage. A small hut or dwelling in an unfrequented place, occupied by a hermit.

Hermodorus. See Architects, list of, 30.

Hermogenes. See Architects, list of, 2.

Herrera. See Architects, list of, 236.



Herring Bone Work. A disposition of bricks or stones laid diagonally (see diagram in the margin), each length receiving the end of the adjoining brick or stone. See Ashlar.

Hewn Stone. That which is reduced to a given form by the use of the mallet and chisel.

Hexaedron or Cube. (Gr. 'Εξ, six, and 'Εδρα, seat.) One of the five regular solids, so called from its having six faces or seats.

Hexagon. ('Εξ and Γωνια, angle.) In geometry, a plain figure bounded by six straight lines, which, when equal, constitute the figure a regular hexagon.

Hexastyle. (Gr. 'Εξ and Στυλος, column.) That species of temple or building having six columns in front. See Colonnade.

Hick-joint Pointing. That species of pointing in which, after the joints are raked out, a portion of superior mortar is inserted between the courses, and made perfectly smooth with the surface. See Pointing.

Hieroglyphics. ('Ιερος, sacred, and Γλυφω, I engrave.) Sculpture or picture writing, which has obtained the name from being most commonly found on sacred buildings. They consist in the expression of a series of ideas by representations of visible objects. The name is, however, more particularly applied to a species of writing used by the ancient Egyptians, which, according to Champollion, was of three different varieties of characters: — 1. The hieroglyphic, properly so called, wherein the representation of the object conveys the idea of the object itself. 2. That in which the characters represent ideas by images of visible objects used as symbols. 3. That consisting of *phonetic characters*, in which the sign does not represent an object but a sound.

Hindoo Architecture. See Indian Architecture, Book I. Chap. II. Sect. 6.

Hinges (from Hang). The metal joints upon which any body turns, such as doors, shutters, &c. There are many species of hinges, which are described in Book II. Chap. III. Sect. 5.

Hip. A piece of timber placed between every two adjacent inclined sides of a hip roof, for the purpose of receiving what are called the jack rafters.

Hip Mould. A term used by some workmen to denote the back of the hip; by others it is used to signify the form or pattern by which the hip is set out.

Hip or Hipped Roof. A roof whose return at the end of a building rises immediately from the wall plate with the same inclination as the adjacent sides. The back of a hip is the angle made on its upper edge, to range with the two sides or planes of the roof, between which it is placed. The *jack rafters* are those short rafters which are shorter than the full-sized ones to fill in against the hips.

Hip or Corner Tiles are those used at the hips of roofs; they are ten inches long, and of appropriate breadth and thickness, and bent on a mould before burning.

Hippodrome. (Gr. 'Ιππος, a horse, and Δρομος, a course.) In ancient architecture, a place appropriated by the Greeks to equestrian exercises, and one in which the prizes were contended for. The most celebrated of these was at Olympia. It was four leagues long, and one in breadth.

Hoard. (Sax. Hoꞃd, to keep.) A timber enclosure round a building, in the course of erection or under repair.

Hod. An utensil employed by labourers for carrying mortar or bricks.

Holdfast. A long nail, with a flat short head for securing objects to a wall.

Holland. See Architects, list of, 307.

Hollow. A concave moulding, whose section is about the quadrant of a circle; called, sometimes, by the workmen a *casement*.

Hollow Newel. An opening in the middle of a staircase. The term is used in contradistinction to solid newel, into which the ends of the steps are built. In the hollow newel, or well hole, the steps are only supported at one end by the surrounding wall of the staircase, the ends next the hollow being unsupported.

Hollow Quoins. Piers of brick or stone made behind the lock gates of canals.

Hollow Wall. One built in two thicknesses, leaving a cavity between them for the purpose of saving materials, or for preserving an uniform temperature in an apartment.

Homestall. A mansion house, or seat in the country.

Homologous. In geometry, the correspondent sides of similar figures. The areas and solid contents of such figures are likewise homologous.

Hontanon, Giov. Gil. de. See Architects, list of, 205.

Hontanon, Roderigo, Gil de. See Architects, list of, 208.

Hoo. See Architects, list of, 114.

Hook. (Sax. Hoce.) A bent piece of iron, used to fasten bodies together, or whereon to hang any article. They are of various kinds.

Hooke. See Architects, list of, 265.

Hookpins. The same as Draw Borepins, which see.

Horizontal Cornice. The level part of the cornice of a pediment under the two inclined cornices.

Horizontal Line. In perspective, the vanishing line of planes parallel to the horizon.

Horizontal Plane. A plane passing through the eye parallel to the horizon, and producing the vanishing line of all level planes.

Horizontal Projection. The projection made on a plane parallel to the horizon. This may be understood perspectively, or orthographically, according as the projecting rays are directed to a given point, or perpendicular to a given point.

Horn. A name sometimes given to the Ionic volute.

Horreum. See Granary.

Horse Block. A square frame of strong boards, used by excavators to elevate the ends of their wheeling planks.

Horse Run. A contrivance for drawing up loaded wheelbarrows of soil from the deep cuttings of foundations, canals, docks, &c., by the help of a horse, which goes backwards and forwards instead of round, as in a *horse-gin*.

Horseshoe Arch. See p. *55*.

Horwood. See Architects, list of, 152.

Hospital. See Book III. Chap. III. Sect. 17.

Hostel or Hotel. (Fr.) Among us this word is used to denote a large inn, or place of public entertainment; but on the Continent it is also used to signify a large house or palace.

Hot House. A general term for the glass buildings used in gardening, and including stoves, greenhouses, orangeries, and conservatories. Pits and frames are mere garden structures, with glass roofs, the sides and ends being of brick, stone, or wood, but so low as to prevent entrance into them; they cannot therefore be considered as hothouses.

House. (Germ. Hause.) A human habitation or place of abode of a family. Among the nations of the east and of the south, houses are flat on the top, to which ascent is general on the outside. As we proceed northward, a declivity of the roof becomes requisite to throw off the rain and snow, which are of greater continuance in higher latitudes. Amongst the ancient Greeks, Romans, and Jews, the houses usually enclosed a quadrangular area or court, open to the sky. This part of the house was by the Romans called the *impluvium* or *cavædium*, and was provided with channels to carry off the waters into the sewers. Both the Roman and Greek house is described by Vitruvius, to whose work we must refer the reader for further information on these heads. The word house is used in various ways; as in the phrase, "a religious house," either the buildings of a monastery, or the community of persons inhabiting them may be designated. In the middle ages, when a family retired to the lodge connected with the mansion, or to their country seat, it was called "keeping their secret house." Every gradation of building for habitation, from the cottage to the palace, is embraced by the word house, so that to give a full account of the requisites of each would occupy more space than could be devoted to the subject in this place; the reader must therefore refer to Book III. Chap. III. Sects. 20 to 24. inclusive.

Housing. The space taken out of one solid for the insertion of the extremity of another, for the purpose of connecting them. Thus the string board of a stair is most frequently notched out for the reception of the steps.

Hovel. An open shed for sheltering cattle, for protecting produce or materials of different kinds from the weather, or for performing various country operations during heavy rains, falls of snow, or severe frosts.

Hovelling. A mode of preventing chimneys from smoking, by carrying up two sides higher than those less liable to receive strong currents of air; or apertures are left on all the sides, so that when the wind blows over the top, the smoke may escape below.

Hue. In painting, any degree of strength or vividness of colour, from its greatest or deepest to its weakest tint.

Hundred or Lime. A denomination of measure which, in some places, is equal to thirty-five, in others to twenty-five, heaped bushels or bags, the latter being the quantity about London, that is, one hundred pecks. The *hundred* is also used for numbering, thus deals are sold by the *long hundred*, or six score. Pales and laths are sold at five score to the hundred if five feet long, and six score if only three feet long. The *hundred weight* is 112 lbs. avoirdupois; the *long hundred weight* is 120 lbs.; so that the former is to the latter as ·93333 to 1.

Hung, double and single. A term applied to sashes; the first when both the upper and lower sash are balanced by weights, for raising and depressing, and the last when only one, usually the lower one, is balanced over the pulleys.

Hut. A small cottage or hovel, generally constructed of earthy materials, as strong loamy clay, &c.

Hydraulics. (Gr. Ὑδωρ and Αυλος, a pipe.) That branch of natural philosophy which treats of the motion of liquids, the laws by which they are regulated, and the effects which they produce. By some authors the term *hydrodynamics* is used to express the science of the motion of fluids generally, whilst the term hydraulics is more particularly applied to the art of conducting, raising, and confining water, and to the construction and performance of waterworks.

Hydrostatics. (Gr. Ὑδωρ and Σταω, I stand.) The science which explains the properties of the equilibrium and pressure of liquids. It is the application of statics to the peculiar constitution of water, or other bodies, existing in the perfectly liquid form. The following is the fundamental law whereon the whole doctrine of the equilibrium and pressure of liquids is founded: when a liquid mass is in equilibrium under the action of forces of any kind, every molecule of the mass sustains an equal pressure in all directions.

Hylmer. See Architects, list of, 177.

Hypæthral. (Gr. Ὑπο, under, and Αιθηρ, the air.) A building or temple without a roof. The temples of this class are arranged by Vitruvius under the seventh order, which had ten columns on each front, and surrounded by a double portico as in dipteral temples. The cell was without roof, whence the name, but it generally had round it a portico of two ranges of columns, one above the other. See Temple.

Hyperbola. (Gr. Ὑπερ, over, and Βαλλω, I throw.) One of the conic sections, being that made by a plane cutting the opposite side of the cone produced above the vertex, or by a plane which makes a greater angle with the base than the opposite side of the cone makes.

Hyperbolic Conoid or Hyperboloid. A solid formed by the revolution of an hyperbola about its axis. See Conoid.

Hyperbolic Cylindroid. A solid formed by the revolution of an hyperbola about its conjugate axis or line through the centre, perpendicular to the transverse axis.

Hyperthyrum. (Gr. Ὑπερ and Θυρα, a door.) The lintel or cross-piece of the aperture of a doorway.

Hypocaustum. (Gr. Ὑπο, under, and Καιω, I burn.) In ancient architecture, a vaulted apartment, from which the heat of the fire was distributed to the rooms above by means of earthen tubes. This contrivance, first used in baths, was afterwards adopted in private houses, and is supposed to have diffused an agreeable and equal temperature throughout the different rooms.

Hypogæum. (Gr.) A term applied among the ancients to those parts of a building which were below the level of the ground.

Hypopodium. A footstool used in the ancient baths.

Hyposcenium. In ancient architecture, the front wall of the theatre, facing the orchestra from the stage.

Hypotrachelium. (Gr. Ὑπο, under, and Τραχηλος, the neck.) The slenderest part of the shaft of a column, being that immediately below the neck of a capital.

I.

Ice House. A subterranean depôt for preserving ice during the winter. The most important advice that can be given to the builder of an ice house is, that it be so thoroughly capable of drainage, from the lowest point of its floor, as to permit no water ever to collect upon it; this accomplished, no difficulty will, with common precaution, prevent the preservation of the ice. The aspect of such a building should be towards the south-east, that the morning sun may expel the damp air which is more prejudicial than warmth. If possible, it should be placed on a declivity for the facility of drainage. At the end of the drain which is to carry away the water arising from the melted ice, a perfect air trap should be placed, to prevent all communication between the external and internal air, from which trap the water should be carried off without the possibility of obstruction. With respect to the dimensions and form of the ice house, the former must depend on the size of the establishment, which, if very large, will require one of a medium diameter, from fifteen to twenty feet; if moderate, one from eight to fifteen feet will be large enough. The best form is the frustum of an inverted cone, ten to twenty feet deep, bricked round, and with double walls, a cavity of four inches being left between them. The ice is sustained on a grated floor, through which the water is rapidly carried off by the drainage first mentioned. The ice is best collected during the severest part of the frost, and should be pounded as laid in the ice house, besides being well rammed down as it is put in. Snow however, hard rammed, will answer when ice cannot be obtained.

Ichnography. (Gr. Ιχνος, a model, and Γραφω, I draw.) The representation of the ground plot of a building. In perspective, it is its representation, intersected by an horizontal plane at its base or groundfloor.

Icosaedron. (Gr. Εικοσι, twenty, and Ἑδρα, seat.) One of the five regular or platonic bodies, bounded by twenty equilateral and equal triangles. It may be regarded as consisting of twenty equal and similar triangular pyramids, whose vertices all meet in the same point; and hence the content of one of these pyramids, multiplied by twenty, gives the whole content of the icosaedron.

Ictinus. See Architects, list of, 12.

Image. In perspective, the scenographic or perspective representation of an object. See Perspective in the body of the work, Book II. Chap. IV. Sect. 2.

Imbow. (Verb.) To arch over or vault.

Impages. A term used by Vitruvius (lib. iv. c. 6.), which has usually been considered as meaning the rails of a door.

Imperial. (Fr.) A species of dome, whose profile is pointed towards the top, and widens towards the base, thus forming a curve of contrary flexure.

Impetus. (Lat.) In mechanics, the same with momentum or force.

Impluvium. (Lat.) In ancient architecture, the outer part of the court of a house which was exposed to the weather. In the summer time, it was the practice to stretch an awning over it.

Impost. (Lat. Impono, I lay on.) The capital of a pier or pilaster which receives an arch. It varies in the different orders; sometimes the whole of the entablature serves as the impost to an arch. The term is applicable to any supporting piece. An impost is said to be mutilated when its projection is diminished, so that it does not exceed that of the adjoining pilaster which it accompanies.

Inbond Jambstone. A bondstone laid in the joint of an aperture.

Incertum. (Lat.) A term used by Vitruvius to designate a mode of building which consisted of small rough stones and mortar, and whose face exhibited irregularly formed masonry, not laid in horizontal courses. See Masonry.

Inch. A measure of length, being the twelfth part of a foot.

Inclination. (Lat.) The approach of one line, which if continued will meet another or the same of two planes.

Inclined Plane. One of the five simple mechanical powers, whose theory is deduced from the decomposition of forces. See p. 389.

Incrustation. (Lat.) Anything, such as mosaic, scagliola, &c., applied by some connecting medium to another body.

Indefinite. (Lat.) Anything which has only one extreme, whence it may be produced infinitely as it is produced from such extreme.

Indented. (Lat.) Toothed together, that is, with a projection fitted to a recess.

Indian Architecture. See Book I. Chap. II. Sect. 6.

Induration. (Lat.) A term applied to the firmer consistence which a body acquires from various causes.

Inertia. (Lat. Iners.) A term applied to that law of the material world which is known to predicate that all bodies are absolutely passive or indifferent to a state of rest or motion, and would continue in those states unless disturbed by the action of some extrinsic force. Inertia is one of the inherent properties of matter.

Infinite. (Lat. Infinitus, boundless.) In geometry, that which is greater than any assignable magnitude; and as no such quantities exist in nature, the idea of an infinite quantity can only, and that most imperfectly, exist in the mind by excluding all notions of boundary or space.

Infirmary. A public building for the reception of the sick; but the term is more generally used to denote a sick-ward or building attached to some public establishment.

Inlaying. The art of laying on some under surface a totally different kind of work to that which the original surface would present. Thus the materials are of no consequence: in stone the inlaying may be of mosaic work or in small pieces, as in wood it may be in patterns made out by different sorts of woods, which is called *marquetry*, or by some, *parquetry*. Veneering is also a species of inlaying.

Inner Plate. The wall plate, in a double-plated roof, which lies nearest the centre of the roof; the side of the other wall plate, called the *outer plate*, being nearer the outer surface of the wall.

Inner Square. The edges forming the internal right angle of the instrument called a square.

Inserted Column. One that is engaged in a wall.

Instruments, mathematical. Those used for describing mathematical diagrams and drawings of every description, when the figures or elementary parts of them are composed of straight lines, circles, or portions of them. The indispensable instruments for such operations are, *a drawing pen, a pair of plain compasses*, commonly called *dividers, a pair of drawing compasses, a port crayon and pencil foot, a pair of bow, of triangular, and of proportional compasses, a protractor*, in the form of a semicircle or rectangle, graduated on the edges, *a plain scale*, and *a parallel rule*.

Insular or Insulated Building. Such as stands entirely detached from any other.

Insulated Column. One detached from a wall, so that the whole of its surface may be seen.

Intaglio. (It.) Sculpture in which the subject is hollowed out, so that the impression from it would present the appearance of a bas-relief.

Intavolata. The same as Cymatium, which see.

Intercepted Axis. In conic sections, that part of the diameter of a curve comprehended between the vertex and the ordinate. It is also called the *abscissa*, and forms an arch of a peculiar kind.

Intercolumniation. (Lat. Inter, between, and Columna, a column.) The distance between two columns measured at the lower part of their shafts. It is one of the most important elements in architecture, and on it depends the effect of the columns themselves, their pleasing proportion, and the harmony of an edifice. Intercolumniations are of five species, *picnostylos, systylos, diastylos, aræostylos*, and *eustylos*, under which several terms each is defined. The subject is also found more largely treated of in Book III. Chap I. Sect. 9.

Interdentels. The space between two dentels. From a comparison of various examples, it seems that the Greeks placed their dentels wider apart than the Romans. In the temple of Bacchus at Teos, the interdentel is two-thirds the breadth of the dentel, and in that of Minerva Polias at Priene, the interdentel is nearly three-fourths. In the temple of Jupiter Stator at Rome, the interdentels are equal to half the breadth of the dentel.

Interior Angle. An angle formed within any figure by two straight lined parts of the perimeter or boundary of the figure, the exterior angle being that which is formed in producing a side of the perimeter of the figure. The term is also applied to the two angles formed by two parallel lines, when cut on each side of the intersecting line.

Interior and opposite Angles. An expression applied to the two angles formed by a line cutting two parallels.

Interjoist. The space or interval between two joists.

Intermodillion. The space between two modillions.

Internal Angle. See Interior Angle.

Interpilaster. The space between two pilasters.

Interquarter. The interval between two quarters.

Interties. Short pieces of timber used in roofing to bind upright posts together, in roofs, partitions, in lath and plaster work, and in walls with timber framework.

Intrados. The interior and lower line or curve of an arch. The exterior or upper curve is called the *extrados*. See Arch.

Invention. (Lat. Invenio, I find.) In the fine arts, the choice and production of such objects as are proper to enter into the composition of a work of art. "Strictly speaking," says Sir Joshua Reynolds, "invention is little more than a new combination of those images which have been previously gathered and deposited in the memory: nothing can come of nothing: he who has laid up no materials can produce no combinations." Though there be nothing new under the sun, yet novelty in art will be attainable till all the combinations of the same things are exhausted, a circumstance that can never come to pass.

Inverted Arch. One wherein the lowest stone or brick is the key-stone. It is used in foundations, to distribute the weight of particular points over the whole extent of the foundation, and hence its employment is frequently of the first importance in constructive architecture.

INVOLUTE. See EVOLUTE.

INWARD ANGLE. The re-entrant angle of a solid. See INTERNAL ANGLE.

IONIC ORDER. See Book III. Chap. I. Sect 5.

IRON. See Book II. Chap. II. Sect. 5.

IRONMONGERY. See Book II. Chap. III. Sect. 10.

IRREGULAR FIGURE. One whose sides, and consequently angles, are unequal to each other.

ISAGON. (Gr. Ἴσος, equal, and Γωνία, an angle.) A figure with equal angles.

ISEMBERT. See ARCHITECTS, list of, 105.

ISIDORUS. See ARCHITECTS, list of, 62.

ISIDORUS OF BYZANTIUM. See ARCHITECTS, list of, 64.

ISODOMUM. (Gr.) One of the methods of building walls practised by the Greeks. It was executed in courses of equal thickness, and with stones of equal lengths. The other method, called *pseudisodomum*, in which the heights, thicknesses, and lengths of the stone were different. There was another mode called EMPLECTON, which see.

ISOSCELES TRIANGLE. One in which two of the sides are of equal length.

IVARA. See ARCHITECTS, list of, 220.

J.

JACK ARCH. One whose thickness is only of one brick.

JACK PLANE. A plane about eighteen inches long, used in taking off the rough surface left by the saw or that of the axe, and of taking off large protuberant parts, to prepare the stuff for the trying plane.

JACK RAFTER. See HIP ROOF.

JACK RIBS. Those in a groin, or in a polygonally-domed ceiling, that are fixed upon the hips.

JACK TIMBER. Any one interrupted in its length, or cut short.

JAMB LININGS. The two vertical linings of a doorway which are usually of wood.

JAMB POSTS. Those introduced on the side of a door, to which the jamb linings are fixed. They are particularly used when partitions are of wood.

JAMB STONES. In stone walls are those which are employed in building the sides of apertures, in which every alternate stone should go entirely through the thickness of the wall.

JAMBS. (Fr.) The sides of an aperture which connect the two sides of a wall. See APERTURE and CHIMNEY.

JAMES, JOHN. See ARCHITECTS, list of, 228.

JEAN D'ECHELLES. See ARCHITECTS, list of, 115.

JERKIN HEAD. The end of a roof not hipped down to the level of the opposite adjoining walls, the gable being carried higher than the level of those walls.

JIB DOOR. A door so constructed as to have the same continuity of surface with that of the partition or wall in which it stands. Its use is to preserve an unbroken surface in an apartment where one door only is wanted nearer to one end of a room than another, and generally for the purpose of preserving uniformity.

JOGGLE. The joint of two bodies so constructed as to prevent them sliding past each other, by the application of a force in a direction perpendicular to the two pressures by which they are held together. Thus the struts of a roof are joggled into the truss posts and into the rafters. When confined by mortise and tenon, the pressure which keeps them together is that of the rafter and the reaction of the truss post. The term is also used in masonry to signify the indentation made in one stone to receive the projection in another, so as to prevent all sliding on the joints. This may be also accomplished by means of independent pieces of material let into the adjacent stones.

JOGGLE PIECE. The truss post in a roof when formed to receive a brace or strut with a joggle.

JOHANNES OF MILETUS. See ARCHITECTS, list of, 65.

JOHN OF PADUA. See ARCHITECTS, list of, 187.

JOINER. The artisan who joins wood by glue, framing, or nails, for the finishings of a building.

JOINERY. The practice of framing or joining wood for the internal and external finishings of houses; thus the covering and lining of rough walls, the covering of rough timbers, the manufacture of doors, shutters, sashes, stairs, and the like, are classed under the head of joinery. See Book II. Chap. III. Sect. 6.

JOINT. The surface of separation between two bodies brought into contact and held firmly together, either by some cementing medium, or by the weight of one body lying on another. A joint, however, is not merely the contact of two surfaces, though the nearer they approach the more perfect the joint. In masonry, the distances of the planes intended to form the joint is comparatively considerable, because of the coarseness of the particles which enter into the composition of the cement.

Jointer. In *joinery* is the largest plane used by the joiner in straightening the face of the edge of the stuff to be prepared. In *bricklaying*, it is a crooked piece of iron forming two curves of contrary flexure by its edges on each side, and is used for drawing, by the aid of the jointing rule, the *coursing* and *vertical* joints of the work.

Jointing Rule. A straight edge used by bricklayers for the regulation of the direction and course of the jointer in the horizontal and vertical joints of brickwork.

Joists. (Fr. Joindre.) The timbers whereto the boards of a floor or the laths for a ceiling are nailed. They rest on the walls or on girders; sometimes on both. When only one tier of joists is used, the assemblage is called *single-flooring;* when two, *double-flooring.*

Jones, Inigo. See **Architects**, list of, 252.

Juffers. An obsolete term for pieces of timber four or five inches square.

Jump. An abrupt rise in a level course of brickwork or masonry to accommodate the work to the inequality of the ground. Also *in quarrying*, one among the various names given to the dislocations of the strata in quarries.

Jumper. A long iron chisel used by masons and miners.

K.

Keep or **Keep Tower.** A term almost synonymous with *donjon.* See **Castle.**

Kendall. See **Architects**, list of, 166.

Kent. See **Architects**, list of, 282.

Kerf. The way made by a saw through a piece of timber, by displacing the wood with the teeth of the saw.

Key. (Sax. Cæge.) An instrument for driving back the bolt of a lock. The *key of a floor* is the board last laid down. In joinery generally a key is a piece of wood let into the back of another in the contrary direction of the grain, to preserve the last from warping.

Key Stone. The highest central stone of an arch. See **Arch.**

Keyed Dado. That which has bars of wood grooved into it across the grain at the back to prevent its warping.

Keyes. See **Architects**, list of, 151.

Keys. In naked flooring are pieces of timber fixed in between the joists by mortise and tenon. When these are fastened with their ends projecting against the sides of the joints, they are called *strutting-pieces.*

Kilderkin. A measure containing eighteen gallons of beer, and sixteen ale measure.

Kiln. A building for the accumulation and retention of heat in order to dry or burn certain materials deposited within them.

King Post. The centre post in a trussed roof. See **Crown Post.**

Kirb Plate. See **Curb Plate.**

Kirb Roof. See **Curb Roof.**

Kitchen. (Fr. Cuisine.) The apartment or office of a house wherein the operations of cookery are carried on.

Knee. A part of the back of a handrailing, of a convex form, being the reverse of a *ramp*, which is also the back of a handrail, but is concave. The term knee is also given to any small piece of timber of a bent or angular form.

Knee Piece or **Knee Rafter.** An angular piece of timber, to which other pieces in the roof are fastened.

Knotting. The preliminary process in painting, to prevent the knots appearing, by covering them with a coat composed of red lead, then white lead and oil, and lastly, a coat of gold size. Sometimes leaf silver is also used.

Knuckle. The joint of a cylindrical form, with a pin as an axis, by which the straps of a hinge are fastened together.

L.

Label. In Gothic architecture, the drip or hood moulding over an aperture when it is returned square.

Labelye. See **Architects**, list of, 285.

Labour. (Lat.) A term in masonry employed to denote the value of a piece of work in consideration of the time bestowed upon it.

Labyrinth. (Gr. *Λαβυρινθος.*) Literally a place, usually subterraneous, full of inextricable windings. The four celebrated labyrinths of antiquity were the Cretan, Egyptian, Lemnian, and Italian. The first has the reputation of being the work of Dædalus to secure the Minotaur; the second is said to have been constructed under the command of Psammeticus, king of Egypt; the third was on the island of Lemnos, and was supported by columns of great beauty; the fourth is reported to have been designed by Porsenna, king of Etruria, as a tomb for himself and his successors.

Labyrinth Fret. A fret, with many turnings, in the form of a labyrinth. See **Fret.**

LACER. See ARCHITECTS, list of, 48.

LACONICUM. (Lat.) One of the apartments in the ancient baths, so called from its having been first used in Laconia.

LACQUER. A yellow varnish, consisting of a solution of shell-lac in alcohol, coloured by gamboge, saffron, annotto, or other yellow, orange, or red colouring matters. The use of lacquer is chiefly for varnishing brass, and some other metals, in order to give them a golden colour and preserve their lustre.

LACTARIUM. (Lat.) Strictly a dairy-house. In ancient architecture, it was a place in the Roman herb market, indicated by a column, called the Columna Lactaria, where foundlings were fed and nourished.

LACUNAR. (Lat.) The ceiling or under surface of the member of an order. Also the under side of the larmier or corona of a cornice. The under side also of that part of the architrave between the capitals of columns. The ceiling of any part in architecture receives the name of lacunar only when it consists of compartments sunk or hollowed, without spaces or bands, between the panels; if it is with bands, it is called *laquear*.

LADY CHAPEL. The name given to a small chapel dedicated to the Virgin, generally, in ancient cathedrals, placed behind the high altar.

LANCET ARCH. One whose head is shaped like the point of a lancet, and generally applied to long narrow windows.

LANDING. The terminating floor of a flight of stairs, either above or below it.

LANFRANC. See ARCHITECTS, list of, 81.

LANFRANI. See ARCHITECTS, list of, 139.

LANGHANS. See ARCHITECTS, list of, 310.

LANTERN. (Fr. Lanterne.) A drum-shaped erection, either square, circular, elliptical, or polygonal, on the top of a dome, or on that of an apartment, to give light.

LAP. The part of one body which lies on and covers another.

LAPO. See ARCHITECTS, list of, 120.

LAQUEAR. See LACUNAR.

LARARIUM. (Lat.) In ancient architecture, the apartment in which the lares or household gods were deposited. It frequently contained also statues of the proprietor's ancestors.

LARDER. The place in which undressed meat is kept for the use of a family.

LARMIER. (Fr.) The same as CORONA, which see.

LATCH. The catch by which a door is held fast.

LATENT HEAT. That which is insensible to the thermometer, upon which the liquid and aeriform states of bodies depend, and which becomes sensible during the conversion of vapours into liquids and of liquids into solids.

LATH. (Sax. Lætta.) A thin cleft piece of wood used in slating, tiling, and plastering. There are two sorts, double and single, the latter being about three-eighths of an inch thick, and the former barely a quarter of an inch. *Pantile laths* are long square pieces of fir, on which the pantiles hang.

LATH BRICKS. A species made in some parts of England. They are twenty-two inches long and six inches broad.

LATH FLOATED AND SET FAIR. Three-coat plasterers' work, in which the first is called *pricking up*; the second *floating*; the third, or finishing, is done with fine stuff.

LATH LAID AND SET. Two-coat plasterers' work, except that the first is called *laying*, and is executed without *scratching*, unless with a broom. When used on walls, this sort of work is generally coloured; when on ceilings, whited.

LATH PLASTERED, SET, AND COLOURED. The same as lath laid, set, and coloured.

LATH PRICKED UP, FLOATED, AND SET FOR PAPER. The same as *lath floated and set fair*.

LATERAL STRENGTH. The resistance which a body will afford at right angles to its grain.

LATTICE. (Fr. Lattis.) A reticulated window, made of laths or strips of iron, separated by glass windows, and only used where air, rather than light, is to be admitted, as in cellars and dairies.

LAUNDRY. An apartment occupied by the laundress of an establishment. It should be spacious and well supplied with every convenience for mangling, drying, and ironing the linen of a family. *Horses*, or slender frames of wood, should be provided for hanging the linen upon, which should be suspended to the timbers of the ceiling by pulleys, by which they may be raised and lowered.

LAVATORY. (Lat.) See CLOISTER.

LAYER. In brickwork and masonry, synonymous with COURSE, which see.

LAYING. In plastering, the first coat on lath of two-coat work, the surface whereof is roughed by sweeping with a broom. The difference between laying and *rendering* being, that the latter is the first coat upon brick.

LAZARHOUSE or LAZARETTO. (Ital.) A hospital for the reception of the poor and those afflicted with contagious diseases. There are many in the southern states of Europe for the performance of quarantine, into which those only are admitted who arrive from countries infected by the plague, or suspected of being so. An account of the principal lazarettos of Europe was published by the celebrated Howard.

Lead. (Sax. Læb.) The heaviest metal next to gold, platina, and mercury, being eleven times heavier than its own bulk of water. See Book II. Chap. II. Sect. 6.

Leanto. A building whose rafters pitch against or lean on to another building or against a wall.

Leaves. (Sax. Leaf.) Ornaments imitated from natural leaves, whereof the ancients used two sorts, natural and imaginary. The former were those of the laurel, palm, acanthus, and olive; but they took great liberties in the representations of all of them.

Ledge. A surface serving to support a body either in motion or at rest. Ledges of doors are the narrow surfaces wrought upon the jambs and sofites parallel to the wall to stop the door, so that when it is shut the ledges coincide with the surface of the door. A ledge, therefore, is one of the sides of a *rebate*, each rebate being formed of two sides. In temporary work the ledges of doors are formed by fillets.

Ledgement. The development of a surface, or the surface of a body stretched out on a plane, so that the dimensions of the different sides may be easily ascertained.

Ledgers. In scaffolding for brick buildings are horizontal pieces of timber parallel to the walls. They are fastened to the *standards*, or upright poles, by cords, to support the *put-logs*, which lie at right angles to and on the walls as they are brought up, and receive the boards for working on.

Ledoux. See Architects, list of, 306.

Legrand. See Architects, list of, 309.

Legs of an Hyperbola. The two parts on each side the vertex.

Legs of a Triangle. The sides which inclose the base.

Length. (Sax. Lenᵹ.) The greatest extension of a body. In a right prism the length is the distance between the ends; in a right pyramid or cone, the length is the distance between the vertex and the base.

Lengthening of Timber is the method of joining several beams, so as to form a long beam of any given length.

Leoni. See Architects, list of, 230.

Lescot. See Architects, list of, 237.

Level. (Sax. Læfel.) A line or surface which inclines to neither side. The term is used substantively to denote an instrument which shows the direction of a straight line parallel to the plane of the horizon. The plane of the sensible horizon is indicated in two ways: by the direction of the plummet, or plumb line, to which it is perpendicular; and by the surface of a fluid at rest. Accordingly, levels are formed either by means of the plumb line, or by the agency of a fluid applied in some particular manner. They all depend, however, upon the same principle, namely, the action of terrestrial gravity.

The carpenter's level consists of a long rule, straight on its lower edge, about ten or twelve feet in length, with an upright fixed to its upper edge, perpendicular to and in the middle of the length, having its sides in the same plane with those of the rule, and a straight line drawn on one of its sides perpendicular to the straight edge of the rule. This standing piece is generally mortised into the other, and finally braced on each side, to secure it from accident, and has its upper end kerfed in three places, viz. through the perpendicular line, and on each side. The straight edge of the transverse piece has a hole, or notch, cut out on the other side equal on each side the perpendicular line. A plummet is suspended by a string from the middle kerf, at the top of the standing piece, to vibrate freely in the hole or notch when hanging at full length. When the straight edge of the level is applied to two distant points, with its two sides placed vertically, if the plummet hangs freely, and the string coincides with the straight line on the standing piece, the two points are level. If not, suppose one of the points to be at the given height, the other must be lowered or raised, as the case may require, till the string is brought to a coincidence with the perpendicular line. By two points is meant two surfaces of contact, as two blocks of wood, or the upper edges of two distant beams.

The uses of the level in carpentry are various, and need not be here detailed. The *mason's level* is formed of three pieces of wood, joined in the form of an isosceles triangle, having a plummet suspended from the vertex over a mark in the centre of the base.

Levelling. The art or act of finding a line parallel to the horizon, or at one or more stations, in order to determine the height of one place with respect to another, for laying grounds even, regulating descents, draining morasses, conducting waters for the irrigation of land, &c.

Lever. In mechanics an inflexible rod, moveable about a fulcrum, or prop, and having forces applied to two or more points in it. The lever is one of the mechanical powers, and being the simplest of them all, was the first attempted to be explained. For its properties see Book II. Chap. I. Sect. 8.

Lever Boards. A set of boards so fastened that they may be turned at any angle to admit more or less light, or to lap upon each other so as to exclude all air or light through apertures.

Lewis or Lewisson. An instrument said to have been used in England by the builders of the middle ages to raise stones of more than ordinary weight to the upper part of a building. It was revived by a French artisan in the reign of Lewis XIV., and is now generally employed. It operates by the pieces forming its dove-tail end being kept in their correspondent places in the stone by a middle straight piece, kept in its situation by a pin passing through it and the dovetail pieces at top, and the combination of the whole, is with a large ring.

Lias. A provincial name adopted by geologists for an argillaceous limestone, which, together with its associated bed, is characterised by peculiar fossils.

Libon. See Architects, list of, 11.

Library. An edifice or apartment for the reception of a collection of books. For remarks on the construction of public libraries see Book III. Chap. III. Sect. 9.

Lights. A term sometimes used to denote the openings of doors, gates, and windows, and other places through which air and light have passage.

Lighthouse. A lofty building, on the top whereof artificial lights are placed to guide ships at sea. For general observations on lighthouses see Book III. Chap. III. Sect. 12.

Like Arcs. In the projection of the sphere, the parts of lesser circles containing an equal number of degrees with the corresponding arcs of greater circles.

Like Figures. In geometry, such as have their angles equal, and the sides about the equal angles proportional.

Like Solids. Those which are contained under like planes.

Lime. (Germ. Leim, glue.) A most useful earth, obtained by exposing chalk, and other kinds of limestones or carbonates of lime, to a red heat, an operation generally conducted in kilns constructed for the purpose, by which the carbonic acid is expelled, and lime, more or less pure, according to the original quality of the limestone, remains, in which state it is called *quicklime*. See Book II. Chap. II. Sect. 10.

Limekiln. One for the purpose of burning lime. They are constructed in a variety of ways, to save expense, or to answer to the particular nature of the fuel.

Limestone. A generic term for those varieties of carbonate of lime which are neither crystallised or earthy, the former being calcareous spar, the latter chalk. When burned they yield quicklime.

Line. (Lat. Linea.) In geometry, a magnitude having only one dimension, and defined by Euclid to be that which has length without breadth. The term is also used to denote a measure of length used formerly in France, namely, the twelfth part of an inch, or $\frac{1}{144}$ of a foot.

Line of Direction. In mechanics, the line in which motion is communicated.

Line, geometrical. In perspective, any straight line in the geometrical or primary line.

Line, horizontal. A line parallel to the horizon. In perspective, it is the vanishing line of horizontal planes.

Line of Station. The intersection of a plane passing through the eye, perpendicular to the picture, and to the geometrical or primary plane with the plane itself.

Line, vertical. The intersection of a vertical plane with the picture passing along the station line.

Line, visual. A ray of light reflected from the object to the eye.

Lines of Light and Shade. Those in which the light and shade of a body are separated. Thus, on a curved surface, it is the line determined by a tangent to the surface in the direction of the rays of light.

Linear Perspective. See Book II. Chap. IV. Sect. 2.

Lining. The covering of the surface of any body with another thin substance. Thus the lining of a wall is a wooden boarding, whose edges are either rebated or grooved and tongued. Lining is distinguished from *casing*, the first being a covering in the interior of a building, whilst the latter is the covering of the exterior part of a building.

Lining out Stuff. (Participle.) The drawing lines on a piece of board or plank so as to cut it into thinner pieces.

Linings of Boxings for window shutters, are the pieces of framework into which the window shutters are folded back.

Linings of a Door. Those of the sides of apertures of doors called the jambs or jamb-linings, that which covers the top or head being the sofite.

Lintel. (Span.) A horizontal piece of timber or stone over a door, window, or other opening to discharge the superincumbent weight. If a wall be very thick, more than one lintel piece will be required, unless scanting of sufficient width be found. In some old books on carpentry lintels are classed under wall plates, but the word is now never used in this sense, unless the joisting or tie-beams rest upon it, in which case it is both a lintel and a wall plate.

List or Listel. The same as Fillet, which see.

Listed Boards. See Boards.

Listing. (Participle.) Cutting the sap wood out from both edges of a board.

Loam. A soil in which clay prevails. It is called heavy or light as the clay may be more or less abundant.

Lobby. (Germ. Laube.) An inclosed space surrounding or communicating with one or more apartments, such as the boxes of a theatre, for instance. By it also is understood a small hall or waiting room, or the entrance into a principal apartment where there is a considerable space between it and a portico or vestibule; but the dimensions, especially as regards the width, will not allow of its being called a vestibule or anti-room.

Lock. (Sax. Loc.) A well-known instrument, consisting of springs and bolts, for fastening doors, drawers, chests, &c. A good lock is a masterpiece in smithery, requiring much art and delicacy to contrive and vary the wards, springs, bolts, and other parts whereof it is composed, so as to adjust them to the places where they are serviceable, and to the various purposes of their use. The structure of locks is so varied, and the number of inventions of their different sorts so extended, that we cannot attempt to enumerate them.

Those placed on outer doors are called *stock locks*, those on chamber doors *spring locks*, and such as are hidden in the thickness of the doors to which they are applied, *mortise locks*. The padlock is too well known to need description here.

The conditions which seem indispensable in a perfect lock are, 1. that certain parts of the lock should be variable in position through a great number of combinations, one only whereof shall allow the lock to be opened or shut; 2. that this last-mentioned combination should be variable at the pleasure of the possessor; 3. that it should not be possible, after the lock is closed and the combination disturbed, for any one, not even the maker of the lock, to discover, by any examination, what may be the proper situations of the parts required to open the lock; 4. that trials of this kind shall not be capable of injuring the works; 5. that it shall require no key; 6. and be as easily opened in the dark as in the light; 7. that the opening and shutting shall be done by a process as simple as that of a common lock; 8. that it should open *without* a key or *with* one, at pleasure; 9. that the keyhole be concealed, defended, or inaccessible; 10. that the key may be used by a stranger without his knowing or being able to discover the adopted combination; 11. that the key be capable of adjustment to all the variations of the lock, and yet be simple; 12. that the lock should not be liable to be taken off and examined, whether the receptacle be open or shut, except by one who knows the method of combination.

The above considerations involve a problem of great mechanical difficulty, which has not yet been solved, though much has been done towards it. For the locks in common use in buildings, see p. 592.

Lodge. A small house, situate in a park or domain, subordinate to the mansion. Also the cottage placed at the gate of the road leading to the mansion.

Logarithms. See p. 246, *et seq.*

Loghouse. A hut constructed of the trunks of trees.

Logistic Spiral. One whose radii are in continued proportion, and in which the radii are at equal angles; or, in other words, a spiral line whose radii every where make equal angles with the tangents.

Lombardo, M. See Architects, list of, 174.

Lombardo, P. See Architects, list of, 173.

Lombardo, Sante. See Architects, list of, 216.

Longimetry. A term used to denote the operation of trigonometry for measuring lengths, whether accessible or inaccessible.

Loop. (Fr.) A small narrow window. A *loophole* is a term applied to the vertical series of doors in a warehouse, from which the goods, in craning, are delivered into a warehouse.

Lorme, Philip de. See Architects, list of, 214.

Lotus. A plant of the water-lily species much used in the architectural ornaments of the early nations, and especially in the capitals of Egyptian columns.

Louis. See Architects, list of, 304.

Lozenge. A quadrilateral figure of four equal sides, with oblique angles.

Luffer Boardings. (Fr. Louvre.) See Boarding Luffer.

Lune or Lunula. The space between two equal arcs of a circle.

Lunette. (Fr.) A cylindric, cylindrical, or spherical aperture in a ceiling. As an example of the term, we may refer to the upper lights in the nave of St. Paul's Cathedral.

Lusarche. See Architects, list of, 110.

Luthern. The same as Dormer, which see.

Lying Panels. Those wherein the fibres of the wood, or the grain of it, lie in an horizontal direction.

Lysis. (Gr.) A plinth or step above the cornice of the podium of ancient temples, which surrounded or embraced the stylobate, whereof an example may be seen in the temple of Fortuna Virilis at Rome.

M.

M Roof. A roof formed by the junction of two common roofs with a vallum between them. The letter M inverted represents this species of covering.

Machicolations. (Fr. Machicoulis.) In castellated architecture are, according to Grose, the projections, supported by brackets or corbels, through which melted lead and stones were dropped on the heads of assailants. They were not probably, however, projecting works, but sometimes were considered as the series of square holes in the vaultings of the portals used for the same purpose.

Machine. (Gr. Μαχανη.) In a general sense, any thing which serves to increase or regulate the effect of a given force. Machines are *simple* or *compound*. The former are the simple mechanical powers, six in number; viz. the lever, the wheel and axle, the pulley, the wedge, the screw, and the funicular machine. The latter are formed by the combination of two or more simple machines, and are classed according to the forces by which they are put in motion, as *hydraulic machines*, *pneumatic machines*, *electrical machines*, &c., or the purposes they are intended to serve, as *military* machines, *architectural* machines, &c.

Machuca. See Architects, list of, 227.

Maderno. See Architects, list of, 249.

Maglione. See Architects, list of, 123.

Magnesian Limestone. An extensive series of beds lying in geological position immediately above the coal measures; so called because the *limestone*, which is the principal member of the series, contains *magnesia*.

Magnitude. (Lat.) A term by which size, extent, or quantity is designated. It was originally applied to the space occupied by any figure; or, in other words, it was applied to objects strictly termed geometrical, and of three dimensions, length, breadth, and thickness, but it has gradually become enlarged in its signification, so as to be given to every kind of quantity that admits of mensuration, or of which greater or less can be predicated; in which sense it was used by Euclid.

Mahogany. A wood often used for doors and window-sashes. See p. 487. The Jamaica mahogany is the hardest and most beautiful, and is distinguished from that of Honduras by the chalky appearance of its fibres. Those from Honduras appear quite dark. After oiling, this distinction is not so clearly observable.

Main Couple. See Couple.

Majano. See Architects, list of, 149.

Malleability. (Lat. Malleus, a hammer.) The property of being susceptible of extension under the blows of a hammer. It is a characteristic of some of the metals, most particularly in gold. Common gold-leaf is not more a two-hundred-thousandth part of an inch in thickness. Five grains may be beaten out so as to cover a surface of more than two hundred and seventy square inches.

Mallet. (Lat.) A large kind of wooden hammer much used by artificers who work with a chisel, as masons, stonecutters, carpenters, joiners, &c.

Maltha. (Gr.) A native bitumen used by the ancients for plastering the walls of their dwellings, &c. An artificial kind was made of pitch, wax, plaster, and grease; another sort was composed of lime slaked with wine, and incorporated with melted pitch and fresh figs.

Mandrel. (Fr. Mandrin.) In machinery, a revolving shank, to which turners affix their work in the lathe.

Mandrocles. See Architects, list of, 6.

Manger. The trough in the stall of a stable wherein is placed the corn or other short food given to live stock, and more especially to horses.

Manlio. See Architects, list of, 203.

Mansard. See Architects, list of, 258.

Mansard, Jules Hardouin. See Architects, list of, 267.

Mansard Roof. (So called from the name of its inventor, François Mansard.) The same as Curb Roof, which see.

Mansion. A large house; a term more usually applied to one in the country. The origin of the word and its application is supposed to be derived from the mansiones, or stationary camps of the Roman soldiers.

Mantle Tree. See Chimney.

Marble. (Fr. Marbre.) A term limited by mineralogists and geologists to the several varieties of carbonate of lime, having more or less of a granular and crystalline texture. Among sculptors, the word is used to denote several compact or granular kinds of stone susceptible of a very fine polish; the varieties of it are extremely numerous. The most valuable sorts used by the ancients were the *Pentelican*, which was white, and was obtained from Mount Penteles in Attica. It was used in the Parthenon and other Athenian buildings, and was also in great repute among the sculptors. The *Parian marble* was, as its name imports, from the island of Paros, in which Mount Marpessus yielded the best, which was called *Marpessian*. The marble of Paros was also sometimes termed

Lychneus, because of its use in making candelabra, and *Lygdinum*, from the promontory of Lygdos. Another of the white marbles of antiquity was that of Mount Hymettus in Attica. The marbles of *Thasus* and *Lesbos* were white, and in great repute. The latter island produced also a black marble. At *Luna*, in Etruria, there was found a marble even whiter than that of Paros. Amongst the white marbles may, moreover, be mentioned the *marmor Phellense* from Mount Phellens; the *marmor Coraliticum*, found near the river Coralios in Phrygia, and termed also *Sangarium*, from another name of the same river. The *marmor Cyzicum* was taken from the quarries of Cyzicus in Asia Minor; the *Synnadicum*, or marmor Phrygium, was obtained from the environs of the city of Synnas in Phrygia, and was of a black ground with small circles. Another sort of marble, which resembled ivory in its colour, was called *chernites*. The marble of *Tænarus* was highly esteemed as a black marble. The *marmor Lybicum*, or *Numidian marble*, called also *marmor Luculleum*, was what the French term *noir antique*. The celebrated *marmor Chium* was excavated from the Mount Pelineus in the island of Chio, and was of a transparent chequered black colour. The *marmor obsidianum* was from Ethiopia, and of the black species, as was the *Proconnesian*, or Cyzican marble, from the island of Proconnesus. That from Mount Taygetes, called *marmor Laconicum*, was the well-known *verd antique* of antiquaries. The marble of *Carystus* was a mingled green; that called the *Atracium*, from Mount Atrax in Thessaly, was a mixture of white, green, blue, and black. The green *Tiberian* and *Augustan* marbles were obtained from Egypt. The *marmor Aphites*, or *Memphites*, which took its first name from its resemblance to the skin of a serpent, and its second from the city of Memphis, where it was found, is the *Serpentino antico* of the Italians. The marble of *Corinth* was yellow, and the *marmor Phengites* of Cappadocia was white, with yellow spots. The *Rhodian marble* was marked with spots resembling gold; that of *Melos* was yellow, and excavated in Mount Acynthus. The varieties of marble used in modern times are exceedingly numerous, and a classification of them would occupy a larger space than can be here given. Except the finest specimens of white marble, they are mostly opaque. Some extremely fine specimens of white marble are to be seen in the Borghese Palace at Rome, which, on being suspended by the centre on a hard body, bend very considerably. It is found that statuary marble exposed to the sun acquires, in time, this property, thus indicating a less degree of adhesion of its parts than it naturally possessed.

Almost every mountainous district of the world produces this mineral, but the finest and most valuable is from Italy. See Book II. Chap. II. Sect. 3.

Marble, polishing of. The material is brought to an even face by rubbing with freestone, afterwards with pumice-stone, and lastly with emery of several colours; but white marble is finished with calcined tin. The Italians polish with lead and emery. The sawing of marble, preparatory to polishing, is by a saw of soft iron, with a continued supply of the sharpest sand and water.

Margin of a Course. That part of the upper side of a course of slates which appears uncovered by the next superior course.

Marigold Window. See Rose Window.

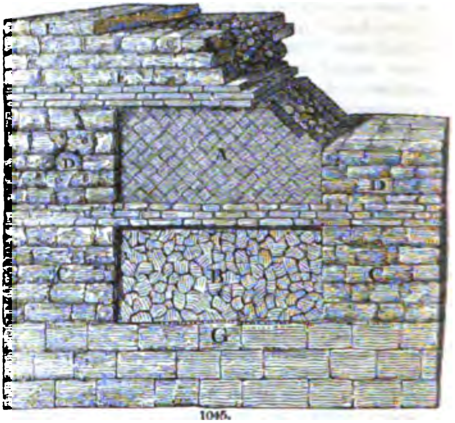
Marmoratum. (Lat.) A cement used by the ancients, formed of pounded marble and lime well beaten together.

Marquetry or Parquetry. (Fr. Marquetrie.) Inlaid work, consisting of different pieces of various coloured woods, of small thickness, glued on to a ground, usually of oak or fir well dried and seasoned, which, to prevent casting and warping, is composed of several thicknesses. It was used by the early Italian builders in cabinet work; and John of Vienna, and others of his period, represented by its means figures and landscapes; but in the present day it is chiefly confined to floors, in which the divers pieces of wood are usually disposed in regular geometrical figures, and are rarely of more than three or four species.

Mascal or Marshall. See Architects, list of, 220.

Masonry. (Fr.) The science of combining and joining stones for the formation of walls and other parts in constructing buildings. When applied in the construction of domes, groins, and circular arches, it is difficult and complicated, and is dependent on a thorough knowledge of descriptive geometry. The subject is treated in the body of this work, Book II. Chap. III. Sect. 3.

Among the ancients, several sorts of masonry were in use, which are described by Vitruvius as follows, in the eighth chapter of his second book: — "The different species of walls," he observes, "are the *reticulatum* (net-like) (*fig.* 1045. A), a method now in general use, and the *incertum* (B), which is the ancient mode. The reticulatum is very beautiful, but liable to split, from the beds of the stones being unstable, and its deficiency in respect of bond. The incertum, on the contrary, course over course, and the whole bonded together, does not present so beautiful an appearance, though stronger than the reticulatum. Both species should be built of the smallest sized stones, that the walls, by sucking up and attaching themselves to the mortar, may last the longer: for as the stones are of a soft and porous nature, they absorb, in dry-



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ing, the moisture of the mortar; and this, if used plentifully, will consequently exercise a greater cementing power; because from their containing a larger portion of moisture, the wall will not, of course, dry so soon as otherwise; and as soon as the moisture is absorbed by the pores of the stones from the mortar, the lime, losing its power, leaves the sand, so that the stones no longer adhere to it, and in a short time the work becomes unsound. We may see this in several monuments about the city (Rome) which have been built of marble, or of stones squared externally, that is, on one face, but filled up with rubble run with mortar. Time in these has taken up the moisture of the mortar, and destroyed its efficacy by the porosity of the surface on which it acted. All cohesion is thus ruined, and the walls fall to decay. He who is desirous that this may not happen to his work should build his two-face walls two feet thick, either of red stone, or of bricks, or of common flint, binding them together with iron cramps run with lead, and duly preserving the middle space or cavity. The materials in this case not being thrown in at random, but the work well brought up on the beds, the upright joints properly arranged, and the face-walls, moreover, regularly tied together, they are not liable to bulge, nor be otherwise disfigured. In these respects one cannot refrain from admiring the walls of the Greeks. They make no use of soft stone in their buildings; when, however, they do not employ squared stones, they use either flint or hard stone, and, as though building with brick, they cross or break the upright joints, and thus produce the most durable work. There are two sorts of this species of work, one called *isodomum* (CC), the other *pseudisodomum* (DD). The first is so called, because in it all the courses are of an equal height; the latter received its name from the unequal heights of the courses. Both these methods make sound work; first, because the stones are hard and solid, and therefore unable to absorb the moisture of the mortar, which is thus preserved to the longest period; secondly, because the beds being smooth and level, the mortar does not escape; and the wall, moreover, bonded throughout its whole thickness, becomes eternal. There is still another method, which is called εμπλεκτον (*emplectum*) (E), in use even among our country workmen. In this species the faces are wrought. The other stones are, without working, deposited in the cavity between the two faces, and bedded in mortar as the wall is carried up. But the workmen, for the sake of despatch, carry up these casing walls, and then tumble in the rubble between them, so that there are thus three distinct thicknesses, namely, the two sides or facings, and the filling in. The Greeks, however, pursue a different course, laying the stones flat, and breaking the vertical joints; neither do they fill in the middle at random, but, by means of bond stones, make the wall solid, and of one thickness or piece. They moreover cross the wall from one face to the other, with bond stones of a single piece, which they call διατονοι (*diatoni*) (F), tending greatly to strengthen the work." We have preferred to give this account in the words of the author himself as the best description, because that of a practical architect, and though capable of some abbreviation, not sufficiently so to justify our own alteration.

Mass. (Germ. Masse.) The quantity of matter whereof any body is composed. The mass of a body is directly as the product of its volume into its density. Multiplied into the constant force of gravity, the mass constitutes the weight; hence the mass of a body is properly estimated by its weight.

Mastic. (Gr. Μαστικη, a species of gum.) A cement of recent introduction into England, employed for plastering walls. It is used with a considerable portion of linseed oil, and sets hard in a few days. From this latter circumstance, and from its being fit for the reception of paint in a very short period, it is extremely useful in works where expedition is necessary.

Masuccio. See Architects, list of, 124.

Materials. (Lat. Materies.) Things composed of matter, or possessing its fundamental properties. Those used in building form the subject of the second Chapter of the second Book of this work, to which the reader is referred.

Mathematics. (Gr. Μαθησις, learning.) The science which investigates the consequences logically deducible from any given or admitted relations between magnitude or numbers.

It has usually been divided into two parts, *pure* and *mixed*. The first is that in which geometrical magnitude or numbers are the subjects of investigation; the last, that in which the deductions so made are from relations obtained by observation and experiment from the phenomena of material nature. This is sometimes called *physics*, or physical science. On the subject of mathematics, the reader is referred, as respects what is necessary for the architect, to ARITHMETIC, and ALGEBRA, and GEOMETRY, in the body of the work, Book II. Chap. I. Sects. 1 and 2.

MATTER. (Lat. Materies.) That which constitutes substance. Of its intimate nature, the human faculty possesses no cognisance, nor either by observation or experiment can data be furnished whereon to found an investigation of it. All that we seem likely to know of it is its sensible properties, some whereof are the foundation of physical science, others of the different subordinate sciences.

MAURITIUS. See ARCHITECTS, list of, 86.

MAUSOLEUM. A term used to denote a sepulchral building, and so called from a very celebrated one erected to the memory of Mausolus, king of Caria, by his wife Artemisia, about 353 B.C. From its extraordinary magnificence, the building just mentioned was in ancient times esteemed the seventh wonder of the world. According to the account of Pliny, it was 111 feet in circumference, and 140 feet high. It is said to have been encompassed by thirty-six columns, and to have been much enriched with sculpture.

MEAN. In mathematics, that quantity which has an intermediate value between several others, formed according to any assigned law of succession. Thus, an *arithmetical mean* of several quantities is merely the *average*, found by dividing the sum of all the quantities by their number. A *geometrical mean* between two quantities, or a *mean proportional*, is the middle term of a duplicate ratio, or continued proportion of three terms; that is, that the first given term is to the quantity sought as that quantity is to the other given term. In arithmetic it is the square root of the product of the two given terms. The *harmonical mean* is a number such that the first and third terms being given, the first is to the third as the difference of the first and second is to the difference of the second and third.

MEASURE. (Lat. Mensura.) In geometry, strictly a magnitude or quantity taken as a unit, by which other magnitudes or quantities are measured. It is defined by Euclid as that which, by repetition, becomes equal to the quantity measured. Thus, in arithmetic, the *measure of a number* is some other number which divides it without a remainder, though, perhaps, such a definition rather intimates the notion of *aliquot parts*. But that meaning on which this article is submitted is the unit or standard by which extension is to be measured. We have measures of length, of superficies, and of volume or capacity. But the two latter are always deducible from the former; whence it is only necessary to establish one unit, namely, a standard of length. The choice of such a standard, definite and invariable, though beset with many and great difficulties, modern science has accomplished. The rude measures of our ancestors, such as the *foot*, the *cubit*, the *span*, the *fathom*, the *barleycorn*, the *hair's breadth*, are not now to be mentioned in matters of science, much more precise standards having been found, and not susceptible of casual variation. Nature affords two or three elements, which, with the aid of science, may be made subservient to the acquisition of the knowledge required. The earth being a solid of revolution, its form and magnitude may be assumed to remain the same in all ages. If this be so, the distance between the pole and the equator may be taken as an invariable quantity; and any part, say a degree, which is a nineteenth part of it, will be constant, and furnish an unalterable standard of measure. So, again, the force of gravity at the earth's surface being constant at any given place, and nearly the same at places under the same parallel of latitude, and at the same height above the level of the sea, the length of a pendulum making the same number of oscillations in a day is constant at the same place, and may be determined on any assumed scale. Thus we have two elements, the length of a degree of the meridian, and the length of a pendulum beating seconds, which nature furnishes for the basis of a system of measures. Others have been suggested, such as the height through which a heavy body falls in a second of time, determined, like the length of the pendulum, by the force of gravity, or the perpendicular height through which a barometer must be raised till the mercurial column sinks a determinate part; for instance, one-thirtieth of its own length; but these are not so capable of accurately determining the standard as the terrestrial degree, or the length of the pendulum.

By an act of Parliament passed in the year 1824, it was declared, in relation to a standard which then was in the custody of the clerk of the House of Commons, whereon were engraved the words and figures *standard yard*, 1760, but which was soon after burnt in the fire of the houses of Parliament, that it should be the unit or only standard measure of extension, and that it should be called the *imperial standard yard*. The act further declared, that if at any time thereafter the said imperial standard yard should be lost, or in any manner destroyed, defaced, or otherwise injured, it should be restored by making, under the directions of the lords of the treasury, a new standard yard, bearing the proportion to a pendulum vibrating seconds of mean time in the latitude of London, in a vacuum, and at the level of the sea, as 36 inches to 39·1393 inches. It was afterwards found that this measure, when nicely examined, was incorrect, as respected the relation of 36 to 39·1393. It seems, too, never to have been directly compared with the pendulum; neither from the difficulty of determining the lengths of the seconds pendulum, except within limits too wide for the purpose in question, could the restoration of the standard be effected with any certainty. Perhaps the only standard that can be safely referred to at the present day is that belonging to the Royal Astronomical Society.

In the English system of linear measures, the unit, as we have above seen, is the yard, which is subdivided into 3 feet, and each of those feet into 12 inches. Of the yard, the multiples are, the pole or perch, the furlong, and the mile; 5½ yards being 1 pole, 40 poles being 1 furlong, and 8 furlongs 1 mile. The pole and furlong, however, are now much disused, distance being usually measured in miles and yards. The English pace is 1⅔ yards = 5 feet. Thus, the following table exhibits the relations of the different denominations mentioned: —

Inches.	Feet.	Yards.	Poles.	Furlongs.	Miles.
1	0·083	0·028	0·00505	0·00012626	0·0000157828
12	1.	0·333	0·06060	0·00151515	0·00018939
36	3.	1·	0·1818	0·004545	0·00056818
198	16·5	5·5	1·	0·025	0·003125
7920	660·	220·	40·	1·	0·125
63360	5280.	1760·	320·	8·	1·

The measures of superficies are the square yard, foot, inch, &c., as under: —

144 square inches are equal to - - - 1 square foot.
9 square feet - - - - - 1 square yard.
2 7/9 square yards - - - - - 1 square pace.
10·89 square paces - - - - 1 square pole.
40 square poles - - - - - 1 square rood.
4 square roods - - - - - 1 square acre.

In which it will be seen that the multiples of the yard are the pole, rood, and acre. Very large surfaces, as of countries, are expressed in square miles. The relations of square measure are given in the following table: —

Square Feet.	Square Yards.	Square Poles.	Square Roods.	Square Acres.
1·	0·1111	0·00367309	0·000091827	0·000022957
9·	1·	0·0330579	0·000826448	0·000206612
272·25	30·25	1·	0·025	0·00625
10890·	1210·	40·	1·	0·25
43560·	4840·	160·	4·	1·

The measures of solids are cubic yards, feet, and inches, 1728 cubic inches being equal to a cubic foot, and 27 cubic feet to one cubic yard. By the act of 1824, the standard measure for all sorts of liquids, corn, and other dry goods, is declared to be the *Imperial gallon*. According to the act in question, the imperial standard gallon contains ten pounds avoirdupois of distilled water, weighed in air at the temperature of 62° Fahrenheit's thermometer, the barometer being at 30 inches. The pound avoirdupois contains 7000 troy grains, and it is declared that a cubic inch of distilled water (temperature 62°, barometer 30 inches) weighs 252·458 grains. Hence the imperial gallon contains 277·274 cubic inches. The gallon is subdivided into *quarts* and *pints*, 2 pints being one quart, and 4 quarts one gallon. Its multiples are the *peck*, which is 2 gallons, the *bushel*, which is 4 pecks, and the *quarter*, which is 8 bushels. The relations of measures of volume are given in the subjoined table: —

Pints.	Quarts.	Gallons.	Pecks.	Bushels.	Quarters.
1	0·5	0·125	0·0625	0·015625	0·001953125
2	1·	0·25	0·125	0·03125	0·00390625
8	4·	1·	0·5	0·125	0·015625
16	8·	2·	1·	0·25	0·03125
64	32·	8·	4·	1·	0·125
512	256·	64·	32·	8·	1·

The old wine gallon contained 231 cubic inches, the old corn gallon 268·8 cubic inches, and the old ale gallon 282 cubic inches. Before noticing the new French, or metre, system of measures, we subjoin a few of the principal ancient ones, English inches: —

1 toise, French = 6 French feet = 6·394665 English feet.
1 foot, do. = 12 French inches = 12·78936 English inches.
1 inch, do. = 12 French lines = 1·06578 English inches.
1 line, do. = 6 French points = 0·088815 English inches.
1 point, do. = ... = 0·0148025 English inches.

According to General Roy, an English fathom : a French toise :: 1000 : 106575.

In the new French system, the *metre*, which is the unit of linear measure, is the ten-millionth part of the quadrant of the meridian = 3·2808992 English feet; and, as its multiples and subdivisions are decimally arranged and named by prefixing Greek numerals, the following table exhibits each: —

Denomination.		English Feet.
Myriametres	10000 metres	= 32808·992
Kilometre	1000	= 3280·8992
Hectometre	100	= 328·08992
Decametre	10	= 32·808992
Metre (the unit)	1	= 3·2808992
Decimetre	0·1	= 0·32808992
Centimetre	0·01	= 0·032808992
Millimetre	0·001	= 0·0032808992

The metre, therefore, is equal to 39·3707904 English inches.

The unit of superficial measure, in the French system, is the *are*, which is a surface of 10 metres each way, or 100 square metres. The centiare is 1 metre square.

Denomination.		English Square Yards.
Hectare	10000 square metres	= 11960·33
Are (the unit)	100	= 119·6033
Centiare	1	= 1·196033

The are, therefore, is equal to 1076·4297 English square feet.

The unit of measures of capacity, in the French system, is the *litre*, a vessel containing a cube of a tenth part of the metre, and equivalent to 0·22009668 British imperial gallon. Its multiples and subdivisions are as follow: —

Denomination.		Eng. Imp. Gallons.
Kilolitre	1000 litres	= 220.09668
Hectolitre	100	= 22·009668
Decalitre	10	= 2·2009668
Litre (the unit)	1	= 0·22009668
Decilitre	0·1	= 0·02209668

The unit of solid measure, or the *stere*, is equal to 35·31658 English cubic feet; therefore,

Denomination.		English Cubic Feet.
Decastere	10 steres	= 353·1658
Stere (the unit)	1	= 35·31658
Decistere	0·1	= 3·531658

Under the word FOOT will be found the length of that measure in the principal places of Europe. We here think it right to add some further continuation of that article as drawn up by the late Dr. Thomas Young from Hutton, Cavallo, Howard, Vega, and others.

	English Feet.	
Altdorff foot	·775	Hutton.
Amsterdam foot	·927 ·930 ·931	H. Cavallo. Howard.
Amsterdam ell	2·233	C.
Ancona foot	1·282	H.
Antwerp foot	·940	H.
Aquileia foot	1·128	H.
Arles foot	·888	H.
Augsburg foot	·972	H.
Avignon = Arles.		
Barcelona foot	·992	H.
Basle foot	·944	H.
Bavarian foot	·968	Beigel.
Bergamo foot	1·431	H.
Berlin foot	·992	H.
Berne foot	·962	Howe.
Besançon foot	1·015	H.
Bologna foot	1·244 1·250	H. Cavallo.

	English Feet.	
Bourg en Bresse foot	1·030	H.
Brabant ell, in Germany	2·268	Vega.
Bremen foot	·955	H.
Brescia foot	1·560	H.
Brescian braccio	2·092	C.
Breslaw foot	1·125	H.
Bruges foot	·749	H.
Brussels foot	·902 ·954	H. V.
Brussels, greater ell	2·278	V.
Brussels, lesser ell	2·245	V.
Castilian vara	2·746	C.
Chambery foot	1·107	H.
China mathematical foot	1·127	H.
China imperial foot	1·051 1·050	H V.
Chinese li	606·000	C.
Cologne foot	·903	H.
Constantinople	2·195 1·165	H.

	English Feet.	
Copenhagen foot	1·049	H.
Cracow foot	1·169	H. V.
Cracow greater ell	2·024	V.
Cracow smaller ell	1·855	V.
Dantzic foot	·923	H.
Dauphiné foot	1·119	H.
Delft foot	·547	H.
Denmark foot	1·047	H.
Dijon foot	1·030	H.
Dordrecht foot	·771	H.
Dresden foot	·929	Wolfe.
Dryden ell=2 feet	1·857	V.
Ferrara foot	1·317	H.
Florence foot	·995	H.
Florence braccio	1·900 1·910	Cavallo.
Franche Comté foot	1·172	H.
Frankfort=Hamburgh	-	H.
Genoa palm	·812 ·809 ·817	H. Cavallo.
Genoa canna	7·300	C.
Geneva foot	1·919	H.
Grenoble=Dauphiné.		
Haarlem foot	·937	H.
Halle foot	·977	H.
Hamburgh foot	·933	H.
Heidelberg foot	·903	H.
Inspruck foot	1·101	H.
Leghorn foot	·992	H.
Leipzig foot	1·034	H.
Leipsig ell	1·833	H.
Leyden foot	1·023	H.
Liege foot	·944	H.
Lisbon foot	·952	H.
Lucca braccio	1·958	H.
Lyons=Dauphiné.		
Madrid foot	·915 ·918	H. How.
Madrid vara	3·263	C.
Maestricht foot	·916	H.
Malta palm	·915	H.
Mantua brasso	1·521	H.
Mantuan braccio=Brescia	-	C.
Marseilles foot	·814	H.
Mechlin foot	·753	H.
Mentz foot	·988	H.
Milan decimal foot	·855	H.
Milan aliprand foot	1·426	H.
Milanese braccio	1·725	C.
Modena foot	2·081	H.
Monaco foot	·771	H.
Montpelier pan	·777	H.
Moravian foot	·971	V.
Moravian ell	2·594	V.
Moscow foot	·928	H.
Munich foot	·947	H.
Naples palm	·861 ·859	H. C.
Naples canna	6·908	C.
Nuremburg town foot	·996 ·997	H. V.
Nuremburg country foot	·907	H.
Nuremburg artillery foot	·961	V.
Nuremburg ell	2·166	V.
Padua foot	1·406	H.
Palermo foot	·747	H.
Paris foot	1·066	H.
Paris metre	3·2808	
Parma foot	1·869	H.
Parmesan braccio	2·242	C.
Pavia foot	1·540	H.
Placentia=Parma	-	C.
Prague foot	·987 ·972	H. V.
Prague ell	1·948	V.
Provence=Marseilles.		
Rhinland foot	1·023 1·030	H. Eytelwein.
Riga=Hamburgh.		
Roman palm	·733	H.
Roman foot	·966	Folkes.
Roman deto, 1-16th foot	·0604	F.
Roman oncia, 1-12th foot	·0806	F.
Roman palmo	·2515	F.
Roman palmo di architettura	·7325	F.
Roman canna di architettura	7·325	F.
Roman staiolo	4·212	F.
Roman canna dei mercanti (8 palms)	6·5365	F.
Roman braccio dei mercanti (4 palms)	2·7876 2·856	F. C.
Roman braccio di tessitor di tela	2·0868	F.
Roman braccio di architettura	2·561	C.
Rouen=Paris	-	H.
Russian archine	2·3626	C.
Russian arschin	2·3333	Phil. Mag.
Russian verschock (1-16th arschin)	·1458	
Savoy=Chamberri	-	H.
Seville=Barcelona	-	H.
Seville vara	2·760	C.
Sienna foot	1·239	H.
Stellin foot	1·224	H.
Stockholm foot	1·073 ·974	H. Celsius.
Strasburg town foot	·956	H.
Strasburg country foot	·967	H.
Toledo=Madrid	-	H.
Trent foot	1·201	H.
Trieste ell for woollens	2·220	H.
Trieste ell for silk	2·107	H.
Turin foot	1·676 1·681	H. C.
Turin ras	1·958	C.
Turin trabuco	10·085	C.
Tyrol foot	1·096	V.
Tyrol ell	2·639	V.
Valladolid foot	·908	H.
Venice foot	1·137 1·140 1·167	H. How. C.
Venice braccio of silk	2·108	C.
Venice ell	2·089	V.
Venice braccio of cloth	2·250	C.
Verona foot	1·117	H.
Vicenza foot	·136	H.
Vienna foot	1·036 1·037	H. How.
Vienna ell	2·557	V.
Vienna post mile	24·888	V.
Vienne in Dauphiné foot	1·058	H.
Ulm foot	·826	H.
Urbino foot	1·162	H.
Utrecht foot	·741	H.
Warsaw foot	1·169	H.
Wesel=Dordrecht	-	H.
Zurich foot	·979 ·984	H. Phil. Mag.

The uncertainty respecting the ancient Greek and Roman measures had almost induced us to refrain from setting down the usually received notions on those subjects, but as we may be accused by the omission of neglect, we subjoin some few: —

SCRIPTURE LONG MEASURE.

			English	
			Feet.	Inches.
1	digit		0	0·912
4	digits	=1 palm	0	3·648
3	palms	=1 span	0	10·944
2	spans	=1 cubit	1	9·888
4	cubits	=1 fathom	7	3·552
1½	fathoms	=1 reed (Ezekiel's)	10	11·328
1⅓	reeds	=1 pole (Arabian)	14	7·104
10	poles	=1 scœnus, or measuring line	145	1·104

GRECIAN LONG MEASURE.

			English Paces of 5 ft.	Ft.	In.
1	dactylus, or digit	- - - - - =	0	0	0·7554
4	dactyli	= 1 doron, or dochme, or palesta =	0	0	3·0218
2½	palestre, &c.	= 1 lichas - - - =	0	0	7·5546
1 1/10	lichas	= 1 orthodoron - - =	0	0	8·3101
1 1/11	orthodoron	= 1 spithame - - - =	0	0	9·0656
1⅓	spithame	= 1 pous, or foot - - =	0	1	0·0875
1⅛	pous	= 1 pygme, or cubit - - =	0	1	1·5984
1 1/9	pygme	= 1 pygons - - - =	0	1	3·109
1⅕	pygon	= 1 pecus, or larger cubit - =	0	1	6·13125
4	pecus	= 1 orgye, or pace - - =	0	6	0·525
100	orgya, or paces	= 1 stadium, aulus, or furlong - =	100	4	4·5
8	stadia, &c.	= 1 million, or mile - - =	805	5	0

ROMAN LONG MEASURE.

			English Paces.	Ft.	In.
6	scrupula	= 1 sicilicum.			
8	scrupula	= 1 duellum.			
1½	duellum	= 1 semniaria.			
18	scrupulas	= 1 digitus transversus - =	0	0	0·725
1⅓	digiti	= 1 unciæ, or inch - - =	0	0	0·967
3	unciæ	= 1 palma minor - - =	0	0	2·901
4	palmæ	= 1 pes, or foot - - =	0	0	11·604
1¼	pes, or foot	= 1 palmipes - - =	0	1	2·505
1⅕	palmipes	= 1 cubit - - - =	0	1	5·406
1⅔	cubits	= 1 gradus - - - =	0	2	5·01
2	gradus	= 1 passus - - - =	0	4	10·02
2	passus	= 1 decempeda - - =	1	4	8·04
25	passus	= 1 stadium - - - =	120	4	4·5
8	stadia	= 1 milliare, or mile - - =	967	0	0

MECHANICS. (Gr. Μηχανη, machine.) That science in natural philosophy treating of forces and powers, and their action on bodies, either directly or by the intervention of machinery. The theory of mechanics is founded on an axiom or principle, called the *law of inertia*, namely, that a body must remain for ever in a state of rest, or in a state of uniform or rectilineal motion, if undisturbed by the action of an external cause. Theoretical mechanics consists, therefore, of two parts: — *Statics*, which treats of the equilibrium of forces; and *dynamics*, or the science of accelerating or retarding forces, and the actions they produce. (See Book II. Chap. I. Sect. 8.) When the bodies under consideration are in a fluid state, these equilibria become respectively *hydrostatics* and *hydrodynamics*.

MECHANICAL CARPENTRY. That branch of carpentry which relates to the disposition of the timbers of a building in respect of their relative strength and the strains to which they are subjected. See Book II. Chap. I. Sect. 11.

MECHANICAL POWERS. See MACHINE.

MEDALLION. A square, or, more properly, a circular table, on which are embossed figures, busts, and the like.

MEDIÆVAL ARCHITECTURE. The architecture of England and the Continent during the middle ages, including the Norman and early Gothic styles.

MELSONBY. See ARCHITECTS, list of, 113.

MEMBER. (Lat.) Any part of an edifice or any moulding in a collection of mouldings, as of those in a cornice, capital, base, &c.

MENAGERIE. (Fr.) A building for the housing and preservation of rare and foreign animals. The ancient Romans of opulence usually had private menageries, a sort of small park attached to their villa, and in them various kinds of animals were placed.

MENSURATION. (Lat.) The science which teaches the method of estimating the magnitudes of lines, superficies, and bodies. See Book. II. Chap. I. Sect. 7.; as applied to measuring and estimating buildings, see Book II. Chap. III. Sect. 14.

MERCIER, DE. See ARCHITECTS, list of, 262.

MERIDIAN LINE. A line traced on the surface of the earth coinciding with the intersection of the meridian of the place with the sensible horizon. It is therefore a line which lies due north and south. In Italy we often find these lines in large churches, as at Santa Maria del Fiore at Florence, the Duomo at Bologna, &c. They are traced on brass rods let into the pavement of the church, and marked with the signs, and otherwise graduated. A hole in the roof permits the sun's rays to fall on them at his culmination, thus marking noon as well as his height each day in the heavens.

Merliano. See Architects, list of, 204.

Meros. (Gr.) The plane face between the channels in the triglyphs of the Doric order.

Mesaulæ. (Gr.) Described by Vitruvius as *itinera* or passages; they were, however, smaller courts. Apollonius Rhodius, in describing the reception of the Argonauts at the palace of Æetes, conducts them first into the vestibule, then through the folding gates into the mesaula, which had *thalami* here and there, and a portico (αιθουσα) on every side.

Meta. (Lat.) A mark or goal in the Roman circus to which the chariots, &c. ran.

Metal. (Gr. Μεταλλον.) A firm, heavy, and hard substance, opaque, fusible by fire, and concreting again when cold into a solid body such as it was before; generally malleable under the hammer, and of a bright glossy and glittering substance where newly cut or broken. The metals conduct electricity and heat, and have not been resolved into other forms of matter, so that they are regarded as simple or elementary substances. Modern chemists have carried the number of metals to forty-two, only seven whereof were known to the ancients; namely, — 1. *Gold*, whose symbol is thus marked ☉; 2. *Silver*, ☽; 3. *Iron*, ♂; 4. *Copper*, ♀; 5. *Mercury*, ☿; 6. *Lead*, ♄; 7. *Tin*, ♃. The *metals* of most use in building are treated of in Book II. Chap. II. Sections 5, 6, and 7.

Metatome. (Gr. Μετα, and Τεμνω, I cut.) The space or interval between two dentels.

Metoche. (Probably from Μετεχαι, I divide.) In ancient architecture a term used by Vitruvius to denote the interval or space between the dentals of the Ionic, or triglyphs of the Doric order. Baldus observes that in an ancient MS. copy of that author, the word metatome is used instead of metoche. This made Daviler suspect that the common text of Vitruvius is corrupt, and that the word should not be metoche but metatome, as it were *section*.

Metopa. (Gr. Μετα, between, and Οπη, a hole.) The square space in the frieze between the triglyphs of the Doric order: it is left either plane or decorated, according to the taste of the architect. In the most ancient examples of this order the metopa was left quite open, whereof notice has been taken at p. 57. in the body of the work.

Metrodorus. See Architects, list of, 52.

Mezzanine. (Ital. Mezzano, middle.) A story of small height introduced between two higher ones.

Mezzo Relievo. See Relievo.

Michelozzi. See Architects, list of, 148.

Middle Post. In a roof, the same as King Post.

Middle Quarters of Columns. A name given to the four quarters of a column divided by horizontal sections, forming angles of forty-five degrees on the plan.

Middle Rail. The rail of a door level with the hand, on which the lock is usually fixed.

Mile. (Lat. Mille passuum, a thousand paces.) A measure of length in England equal to 1760 yards. The Roman pace was 5 feet; and a Roman foot being equal to 11·62 modern inches, it follows that the ancient Roman mile was equivalent to 1614 English yards, or very nearly eleven twelfths of an English statute mile. The measure of the English mile is incidentally defined by an act of parliament passed in the 35th of Elizabeth, restricting persons from erecting new buildings within three miles of London, in which act the mile is declared to be 8 furlongs of 40 perches each, and each perch equal to 16½ feet.

Milk Room. See Dairy.

Millstone Grit. A coarse grained quartzose sandstone. It is extracted from the group of strata which occur between the mountain limestone and the superincumbent coal formations.

Minaret. (Arab. Menarah, a lantern.) A slender lofty turret, rising by different stages or stories, surrounded by one or more projecting balconies, common in Mohammedan countries, being used by the priests for summoning (from the balconies) the people to prayers at stated periods of the day.

Minion. An iron ore which, mixed with a proper quantity of lime, makes an excellent water cement.

Minster. A church to which an ecclesiastical fraternity has been or is attached. The name is applied occasionally to cathedrals, as in the case of York Minster.

Minute. (Lat.) A term given to the sixtieth part of the lower diameter of a column, being a subdivision used for measuring the minuter parts of an order.

Mischia. See Scagliola.

Mitchel. A name given by workmen to Purbeck stones of twenty-four by fifteen inches when squared for building.

Miter or **Mitre.** See Bevel.

Miter Box. See Box for Miter.

Mixed Angle. An angle of which one side is a curve and the other a straight line.

Mixed Figure. One composed of straight lines and curves, being neither entirely the sector nor the segment of a circle, nor the sector nor segment of an ellipsis, nor a parabola, nor an hyperbola.

MNESICLES. See ARCHITECTS, list of, 14.

MNESTHES. See ARCHITECTS, list of, 20.

MOAT. (Lat.) An excavated reservoir of water surrounding a house, castle, or town.

MODEL. (Lat.) An original or pattern proposed for any one to copy or imitate. Thus St. Paul's may be, though not strictly so, said to be built after the model of St. Peter's at Rome.

The word is also used to signify an artificial pattern made of wood, stone, plaster, or other material, with all its parts and proportions, for the satisfaction of the proprietor, or for the guide of the artificers in the execution of any great work. In all great buildings, the only sure method of proceeding is to make a model in relievo, and not to trust entirely to drawings.

MODILLION. (Fr.) A projection under the corona of the richer orders resembling a bracket. In the Grecian Ionic there are no modillions, and they are seldom found in the Roman Ionic. Those in the frontispiece of Nero at Rome consist of two plain faces separated by a small cyma reversa, and crowned with an ovolo and bead. In the frieze of the fourth order of the Coliseum, the modillions are cut in the form of a cyma reversa. For further information on the subject the reader may refer to p. 797. in the body of the work.

MODULAR PROPORTION. That which is regulated by a module. See MODULE.

MODULATION. (Lat.) The proportion of the different parts of an order.

MODULE. (Lat.) A measure which may be taken at pleasure to regulate the proportions of an order, or the disposition of the whole building. The diameter or semi-diameter of the column at the bottom of the shaft has usually been selected by architects as their module; and this they subdivide into parts or minutes. Vignola has divided his module, which is a semi-diameter, into 12 parts for the Tuscan and Doric, and into 18 for the other orders. The module of Palladio, Cambray, Desgodetz, Le Clerc, and others, is divided into 30 parts or minutes in all the orders. Some have divided the whole height of the column into 20 parts for the Doric, 22½ for the Ionic, 25 for the Corinthian, &c., one whereof is taken for the module by which the other parts are to be regulated.

There are two ways by which the measures or proportions of buildings may be determined. First, by a constant standard measure, which is commonly the diameter of the lower part of the column, termed a module, and subdivided into sixty parts called minutes. In the second there are no minutes, nor any certain or stated divisions of the module, but it is divided into as many parts as may be deemed requisite. Thus the height of the Attic base, which is half the module, is divided into three to obtain the height of the plinth, or into four for that of the greater torus, or into six for that of the lesser torus. Both these species of measurement have been used by ancient as well as modern architects, but the latter was that chiefly used by the ancients, and was preferred by Perrault.

Vitruvius having lessened his module in the Doric order, which in the other orders is the diameter of the lower part of the column, and having reduced the great module to a mean one, which is a semi-diameter, Perrault reduces the module to a third part for a similar reason, namely, that of determining the different measurements without a fraction. Thus, in the Doric order, besides that the height of the base, as in the other orders, is determined by one of these mean modules, that same module furnishes the height of the capital, architrave, triglyphs, and metopæ. But the smaller module obtained from a third of the diameter of the lower part of the column has uses considerably more extensive, inasmuch as by it the heights of pedestals, of columns, and entablatures in all the orders may be obtained without a fraction

MODULUS OF ELASTICITY. A term in relation to elastic bodies, which expresses the weight of themselves continued, which would draw them to a certain length without destroying their elastic power.

MOLE. (Sax.) A pier of stone for the shelter of ships from the action of the waves.

Amongst the Romans the term was applied, as in the case of the mole of Adrian (castle of St. Angelo at Rome), to a kind of circular mausoleum.

MOMENTUM. (Lat.) The impetus, force, or quantity of motion in a moving body. The word is sometimes used simply for the motion itself.

MONASTERY. A house for the reception of religious devotees, but more properly applied to one for the habitation of monks.

MONKEY. See FISTUCA.

MONOLITHAL. (Gr. *Μονος*, one, *Λιθος*, a stone.) A work consisting of a single stone; such works are found in many parts of the world.

MONOPTERAL. (Gr.) A species of temple of a round form, which had neither walls nor cella, but only a cupola sustained by columns. See TEMPLE.

MONOTRIGLYPH. (Gr.) A term applied to an intercolumniation in which only one triglyph and two metopæ are introduced.

Montereau, De. See Architects, list of, 116.

Monument. (Lat. Moneo.) A structure raised to perpetuate the memory of some eminent person, or to serve as a durable token of some extraordinary event. Monuments at first consisted of stones built over the graves of the dead, on which were engraved the name and frequently a description of the actions of the persons whose memory they are to record. Monuments were differently formed. Thus some are pyramids, others obelisks; in some cases a square stone, in others a circular column serves the purpose.

Moorstone. A species of granite found in Cornwall and some other parts of England, and very serviceable in the coarser parts of a building. Its colours are chiefly black and white, and it is very coarse. In some parts of Ireland immense beds of it are found.

Moresque Architecture. The style of building peculiar to the Moors and Arabs. See Arabian Architecture, Book I. Chap. II. Sect. 10.

The word Moresque is also applied to a kind of painting in that style used by the Moors. It consists in many grotesque pieces and compartments, promiscuously, to appearance, put together, but without any perfect figure of man or animal. The style is sometimes called *Arabesque*.

Mortar. (Dutch, Morter.) The calcareous cement used in building, compounded of burnt limestone and sand. See Book II. Chap. II. Sect. 10.

Mortice or **Mortise.** (Fr. Mortoise, probably from the Latin Mordeo, to bite.) In carpentry and joinery, a recessed cutting within the surface of a piece of timber, to receive a projecting piece called a *tenon*, left on the end of another piece of timber, in order to fix the two together at a given angle. The sides of the mortice are generally four planes at right angles to each other and to the surface, whence the excavation is made.

Mosaic. (It. Mosaico.) A mode of representing objects by the inlaying of small cubes of glass, stone, marble, shells, wood, &c. It was a species of work much in repute among the ancients, as may be gathered from the numerous remains of it. It is supposed to have originated in the east, and to have been brought from Phœnicia to Greece, and thence carried to Rome. The term Mosaic work is distinguished from *marquetry* by being only applied properly to works of stone, metal, or glass. The art continues to be practised in Italy at the present day with great success.

Mosque. (Turk. Moschet.) A Mohammedan temple or place of worship. The earliest Arabian mosques were decorated with ranges of a vast number of columns, often belonging originally to other buildings. Those of the Turks, on the other hand, are more distinguished for the size and elevation of their principal cupolas. Each mosque is provided with a minaret, and commonly with a fountain of water, with numerous basins for ablutions.

Moston. See Architects, list of, 170.

Mould. A term used to signify a pattern or contour by which any work is to be wrought.

The *glazier's moulds* are of two sorts, one whereof is used for casting the lead into long *rods* or *cames*, fit for drawing through the vice in which the grooves are formed. This they sometimes call the *ingot mould*. The other is for moulding the small pieces of lead, a line thick and two lines broad, which are fastened to the iron bars of casements.

The *mason's mould*, also called *caliber*, is a piece of hard wood or iron, hollowed on the edge, answering to the contours of the mouldings or cornices to be formed. The ends or heading joints being formed as in a cornice by means of the mould, the intermediate parts are wrought down by straight-edges, or circular templets, as the work is straight or circular on the plan. When the intended surface is required to be very exact, a reverse mould is used, in order to prove the work, by applying the mould in a transverse direction of the arrises.

Moulds, among plumbers, are the tables on which they cast their sheets of lead, and are simply called *tables*. They have others for casting pipes without soldering.

The moulds for foundery are described Book II. Chap. III. Sect. 11.

Mouldings. The ornamental contours or forms applied to the edges of the projecting or receding members of an order. The regular mouldings are the *fillet*, *listel*, or *annulet*; the *astragal*, or *bead*; the *torus*, the *scotia*, or *trochilus*; the *echinus*, *ovolo*, or *quarter-round*; the *cyma reversa*, *inverted cyma*, or *ogee*; the *cyma recta*, the *cavetto*, or *hollow*. See p. 684.

Mouldings are divided into two classes — Grecian and Roman. The first are formed by some conic section, as a portion of an ellipse or hyperbola, and sometimes even of a straight line in the form of a *chamfer*. The Roman mouldings are formed by arcs of circles, the same moulding having the same curvature throughout.

For Norman mouldings, see p. 174.

Mouth, Bird's. See Bird's Mouth.

Muel, le. See Architects, list of, 254.

Mullion or **Munnion.** In pointed architecture, the vertical post or bar which divides a window into several lights.

Muniment House. A strong, properly fire-proof, apartment in public or private buildings, for the keeping and preservation of evidences, charters, seals, &c., called muniments.

Mural. (Lat.) Belonging to a wall. Thus a monumental tablet affixed to a wall is called a *mural monument*; an arch inserted into or attached to a wall is called a *mural arch*; and columns placed within or against a wall are called *mural columns*.

Museum. (Gr. Μουσειον.) A repository of natural, scientific, and literary curiosities, or of works of art. See Book III. Chap. III. Sect. 10.

Mustius. See Architects, list of, 45.

Mutilated Cornice. One that is broken or discontinued.

Mutilation. (Lat.) The defacing or cutting away of any regular body. The word is applied to statues and buildings where any part is wanting.

Mutius, C. See Architects, list of, 31.

Mutule. (Lat.) A projecting ornament of the Doric cornice, which occupies the place of the modillion in the other order, and supposed to represent the ends of rafters. The mutule has always been assumed as an imitation of the end of a wooden rafter; hence, say the advocates for a timber type, they are properly represented with a declination towards the front of the coronas.

Mylne. See Architects, list of, 311.

N.

Nail. (Sax. Næȝel.) A small metal spike for fastening one piece of timber to another. The sorts of nails are very numerous. The principal are here enumerated. *Back nails*, whose shanks are flat so as to hold fast but not open the wood. *Clamp nails*, are for fastening clamps. *Clasp nails*, or *brads*, are those with flatted heads, so that they may clasp the wood. They also render the wood smooth, so as to admit of a plane going over it. The sorts of most common use in building are known by the names of *ten-penny*, *twenty-penny* and *two-shilling nails*. *Clench nails* are such as are used by boat and barge builders, sometimes with boves or nuts, but often without. They are made with clasp heads for fine work, or with the head beat flat on two sides. *Clout nails*, used for nailing clouts on axle-trees, are flat headed, and iron work is usually nailed on with them. *Deck nails*, for fastening decks in ships and floors nailed with planks. *Dog* or *jobent nails*, for fastening the hinges of doors, &c. *Flat points* are of two sorts, *long* and *short*; the former much used in shipping, and useful where it is necessary to hold fast and draw without requiring to be clenched; the latter are furnished with points to drive into hard wood. *Lead nails*, used for nailing lead, leather, and canvas to hard wood, are the same as clout nails dipped in lead or solder. *Port nails*, for nailing hinges to the ports of ships. *Ribbing nails*, used for fastening the ribbing to keep the ribs of ships in their place while the ship is building. *Rose nails* are drawn square in the shank. *Rother nails*, chiefly used for fastening rother irons to ships. *Scupper nails*, much in use for fastening leather and canvas to wood. *Sharp nails*, much used in the West Indies, and made with sharp points and flat shanks. *Sheathing nails*, for fastening sheathing boards to ships; their length is usually three times the thickness of the board. *Square nails* are of the same shape as sharp nails, chiefly used for hard wood. *Brads* are long and slender nails without heads, used for thin deal work to avoid splitting. To these may be added *tacks*, the smallest sort whereof serve to fasten paper to wood; the *middling* for medium work; and the *larger size*, which are much used by upholsterers. These are known by the name of *white tacks*, *two-penny*, *three-penny*, and *four-penny tacks*. See Adhesion.

Nail-headed Moulding. One common in Norman buildings, and so called from being formed by a series of projections resembling the heads of nails or square knobs. See p. 174.

Naked. A term applied either to a column or wall to denote the face or plain surface from which the projections rise.

Naked Flooring. See p. 540.

Naked of a Wall. The remote face whence the projections take their rise. It is generally a plain surface, and when the plan is circular the naked is the surface of a cylinder with its axis perpendicular to the horizon.

Naos or Nave. (Gr. Ναος.) See Cell.

Natural Bed of a Stone. The surface from which the laminæ were separated. In all masonry it is important to its duration that the laminæ should be placed perpendicular to the face of the work, and parallel to the horizon, inasmuch as the connecting substance of these laminæ is more friable than the laminæ themselves, and therefore apt to scale off in large flakes, and thus induce a rapid decay of the work.

Naumachia. (Gr. from Ναυς, a ship, and Μαχη, a battle.) In ancient architecture, a place for the show of mock sea engagements, little different from the circus and amphitheatre, since this species of exhibition was often displayed in those buildings.

Nave. (Gr. *Ναος.*) The body of a church or place where the people are seated, reaching from the rail or partition of the choir to the principal entrance. See Cell.

Nebuly Moulding. (Lat. Nebula.) An ornament in Norman architecture, whose edge forms an undulating or wavy line, and introduced in corbel tables and archivolts. See p. 174.

Neck of a Capital. The space, in the Doric order, between the astragal on the shaft and the annulet of the capital. Some of the Grecian Ionic capitals are with necks below them, as in the examples of Minerva Polias and Erectheus, at Athens. But the Ionic order has rarely a neck to the capital.

Needle. An horizontal piece of timber serving as a temporary support to some superincumbent weight, as a pier of brickwork, and resting upon posts or *shores*, while the lower part of a wall, pier, or building is being underpinned or repaired.

Nervures. A name given by French architects to the ribs bounding the sides of a groined compartment of a vaulted roof, as distinguished from the ribs which diagonally cross the compartment.

Net Measure. That in which no allowance is made for finishing, and in the work of artificers, when no allowance is made for the waste of materials.

Newel. The upright cylinder or pillar, round which, in a winding staircase, the steps turn, and are supported from the bottom to the top. In stairs, geometrical for instance, where the steps are *pinned* into the wall, and there is no central pillar, the staircase is said to have an open *newel.*

Niche. (Fr. probably from *Νεοσσια*, a nest.) A cavity or hollow place in the thickness of a wall for the reception of a statue, vase, &c. See Book III. Chap. I. Sect. 21.

Nicola da Pisa. See Architects, list of, 121.

Nicon. See Architects, list of, 51.

Nidged Ashlar. A species of ashlar used in Aberdeen. It is brought to the square by means of a cavil or hammer with a sharp point, which reduces the roughness of the stone to a degree of smoothness according to the time employed. When stone is so hard as to resist the chisel and mallet, the method described is the only way in which it can be dressed.

Nogs. The same as Wood Bricks, which see. The term is chiefly used in the north of England.

Nogging. A species of brickwork carried up in panels between quarters.

Nogging-pieces. Horizontal boards laid in brick-nogging, and nailed to the quarters for strengthening the brickwork. They are disposed at equal altitudes in the brickwork.

Nonagon. (Gr.) A geometrical figure having nine sides and nine angles.

Normal Line. In geometry, one which stands at right angles to another line.

Norman Architecture. See Book I. Chap. III. Sect. 2.

Normand. See Architects, list of, 172.

Nosing of a Step. The projecting part of the tread-board or cover which stands before the riser. The nosing is generally rounded, so as to have a semicircular section; and in the better sort of staircases a fillet and hollow is placed under the nosing.

Notch-board. A board which is grooved or notched for the reception and support of the ends of steps in a staircase.

Notching. A hollow cut from one of the faces of a piece of timber, generally made rectangular in section.

Nucleus. (Lat.) In ancient architecture, the internal part of a floor, which consisted of a strong cement, over which the pavement was laid with mortar.

Nymphæum. (Gr.) A name used by the ancients to denote a picturesque grotto in a rocky or woody place, supposed to be dedicated to, and frequented by, the nymphs. The Romans often made artificial nymphæa in their gardens. In Attica, the remains of a nymphæum are still to be seen decorated with inscriptions and bassi relievi, from the rude workmanship of which it may be presumed that the grotto is of very ancient date.

O.

Oak. (Sax. Ac, Æc.) A forest tree, whose timber is, from its strength, hardness, and durability, the most useful of all in building. See Book II. Chap. II. Sect. 4.

Obelisk. (Probably from *Οϐελος*, a spit, brooch, or spindle, or a long javelin.) A lofty pillar of a rectangular form, diminishing towards the top, and generally ornamented with inscriptions and hieroglyphics. The upper part finishes generally with a low pyramid, called a *pyramidion.* The proportion of the thickness to the height is nearly the same in all obelisks; that is, between one ninth and one tenth, and their thickness at top is never less than half, nor greater than three fourths, of that at bottom. Egypt abounded with obelisks, which were always in a single block of stone; and many have been removed thence to Rome and other places. The following table exhibits a list of the principal obelisks whereof there is any record, or which are at present known, being thirty-three in number.

Situation.	Height.	Thickness.	
		At top.	Below.
	Eng. Feet.	Eng. Feet.	Eng. Feet.
Two large obelisks, mentioned by Diodorus Siculus	158·2	7·9	11·8
Two obelisks of Nuncoreus, son of Sesostris, according to Herodotus, Diodorus Siculus, and Pliny	121·8	6·6	10·5
Obelisk of Rhameses, removed to Rome by Constantius	118·4	6·2	10·2
Two obelisks, attributed by Pliny to Smerres and Eraphius	106·0	5·9	9·8
Obelisks of Nectanabis, erected near the tomb of Arsinöe by Ptolemy Philadelphus	105·5	5·3	9·2
Obelisk of Constantius, restored and erected in front of S. Giovanni Laterano at Rome	105·5	6·2	9·6
Part of one of the obelisks of the son of Sesostris, in the centre of the piazza in front of St. Peter's	82·4	5·8	9·4
Two at Luxor	79·1	5·3	8·0
Obelisk of Augustus from the Circus Maximus, now in the piazza del Popola at Rome	78·2	4·5	7·4
Two in the ruins at Thebes, still remaining	72·8	5·0	7·5
Obelisk of Augustus, raised by Pius VI. in the Piazza di Monte Citorio	71·9	4·9	7·9
Two obelisks, one at Alexandria, vulgarly called Cleopatra's Needle, and the other at Heliopolis	67·1	5·1	8·1
Obelisk by Pliny, attributed to Sothis	63·3	4·5	5·1
Two obelisks in the ruins of Thebes	63·3	4·5	5·1
Great obelisk at Constantinople	59·7	4·5	7·2
Obelisk in the Piazza Navona, removed from the Circus of Caracalla	54·9	2·9	4·5
Obelisk at Arles	50·1	4·5	7·4
Obelisk from the Mausoleum of Augustus, now in front of the church of Sta. Maria Maggiore at Rome	48·3	2·9	4·3
Obelisk in the gardens of Sallust, according to Mercati	48·3	2·9	4·3
Obelisk at Bijije in Egypt	42·9	2·6	4·2
Small obelisk at Constantinople, according to Gyllius	34·2	3·9	5·9
The Barberini Obelisk	30·0	2·2	3·9
Obelisk of the Villa Mattei	26·4	2·2	2·7
Obelisk in the Piazza della Rotunda	20·1	2·1	2·4
Obelisk in the Piazza di Minerva	17·6	2·0	2·6
Obelisk of the Villa Medici	16·1	1·9	2·4

Oblique Line. One which stands, in respect to another, at a greater angle than ninety degrees.

Oblique Angle. One that is greater or less than a right angle.

Oblique-angled Triangle. One that has no right angle.

Oblique Arches. Such as cross an opening obliquely to the front face of it.

Oblong. A rectangle of unequal dimensions.

Observatory. (Fr.) A building for the reception of instruments and other matters for observing the heavenly bodies. See Book III. Chap. III. Sect. 11.

Obtuse. (Lat.) Any thing that is blunt.

Obtuse-angled Triangle. One which has an obtuse angle.

Obtuse Section of a Cone. Among the ancient geometricians a name given to the hyperbola.

Octagon. (Gr. Οκτω and Γωνια, angle.) A figure having eight sides and eight angles.

Octahedron. (Gr.) One of the five regular bodies bounded by eight equal and equilateral triangles.

Octastyle. (Gr. Οκτω and Στυλος.) That species of temple or building having eight columns in front. See **Colonnade.**

Odeum. (Gr.) Among the Greeks, a species of theatre wherein the poets and musicians rehearsed their compositions previous to the public production of them.

Odo. See **Architects**, list of, 88.

Oecus. See **Hall.**

Offices. The apartments wherein the domestics discharge the several duties attached to the service of a house; as kitchens, pantries, brewhouses, and the like.

Offsets. The horizontal projections from the faces of the different parts of a wall where it increases or diminishes in thickness.

Ogee. A moulding, the same as the Cyma reversa, which see.

Ogive. A term used by French architects to denote the Gothic vault, with its ribs and cross springers, &c.

Ololzago. See Architects, list of, 194.

One pair of Stairs. An expression signifying the first story or floor above that floor level with, or raised only by a few steps above, the ground, which latter is thence called the ground floor.

Opæ. (Gr. Οπη.) The beds of the beams of a floor or roof between which are the Metopæ, which see.

Openings. (Sax.) Those parts of the walls of a building which are unfilled for admitting light, ingress, egress, &c. See Aperture.

Opisthodomus. (Gr.) The same as the Roman *posticum*, being the enclosed space behind a temple.

Opposite Angles. Those formed by two straight lines crossing each other, but not two adjacent angles.

Opposite Cones. Those to which a straight line can be applied on the surfaces of both cones.

Opposite Sections. The sections made by a plane cutting two opposite cones.

Optic Pyramid. In perspective, that formed by the optic rays to every point of an object.

Optic Rays. Those which diverge from the eye to every part of an original object.

Orangery. A gallery or building in a garden or parterre opposite to the south. See Green-house. The most magnificent orangery in Europe is that of Versailles, which is of the Tuscan order, and with wings.

Oratory. (Lat.) A small apartment in a house, furnished with a small altar, crucifix, &c., for private devotion. The ancient oratories were small chapels attached to monasteries, in which the monks offered up their prayers. Towards the sixth and seventh centuries the oratory was a small church, built frequently in a burial place, without either baptistery or attached priest, the service being performed by one occasionally sent for that purpose by the bishop.

Orb. (Lat. Orbis.) A knot of foliage or flowers placed at the intersection of the ribs of a Gothic ceiling or vault to conceal the mitres of the ribs.

Orchestra. (Gr. Ορχεομαι.) In ancient architecture, the place in the theatre where the chorus danced. In modern theatres it is the enclosed part of a theatre, or of a music-room wherein the instrumental and vocal performers are seated.

Orcheyarde. See Architects, list of, 160.

Order. (Lat.) An assemblage of parts, consisting of a base, shaft, capital, architrave, frieze, and cornice, whose several services requiring some distinction in strength, have been contrived in five several species — Tuscan, Doric, Ionic, Corinthian, and Composite; each of these has its ornaments, as well as its general fabric, proportioned to its strength and use. There are five orders of architecture, the proper understanding and application whereof constitute the foundation of all excellence in the art. See Book III. Chap. I. Sect. 2. on the Orders generally.

Order, Composite. See Book III. Chap. I. Sect. 7.

Order, Corinthian. See Book III. Chap. I. Sect. 6.

Order, Doric. See Book III. Chap. I. Sect. 4.

Order, Ionic. See Book III. Chap. I. Sect. 5.

Order, Tuscan. See Book III. Chap. I. Sect. 3.

Orders above Orders. See Book III. Chap. I. Sect. 11.

Ordinate. In geometry and conics, a line drawn from any point of the circumference of an ellipsis or other conic section perpendicular to, and across the axis, to the other side.

Ordonnance. (Fr. from the Lat.) The perfect arrangement and composition of any architectural work. It applies to no particular class, but the term is general to all species in which there has existed anything like conventional law.

Organical Description of a Curve. The method of describing one upon a plane by continued motion.

Oriel or Oriel Window. (Etym. uncertain.) A large bay or recessed window in a hall, chapel, or other apartment. It ordinarily projects from the outer face of the wall either in a semi-octagonal or diagonal plan, and is of varied kinds and sizes. In large halls its usual height is from the floor to the ceiling internally, and it rises from the ground to the parapet on the outside; sometimes it consists only of one smaller window supported by corbels, or by masonry projecting gradually from the wall to the sill of the window. Milner, the learned and good Catholic bishop, in his *History of Winchester*, draws a difference between the bow and oriel window. The first projected circularly, and was formerly called a compass or embowed window; whilst the projection of the last was made up of angles and straight lines forming generally the half of a hexagon, octagon, or decagon, and was better known by the name of *bay window*, *shot window*, or *outcast window*, a distinction, however, not generally observed.

Origin and Progress of Architecture. See Book I. Chap. I. Sect. 2.

Original Line, Plane, or Point. In perspective, a line, plane, or point referred to the object itself.

Orle. (Ital.) A fillet under the ovolo or quarter round of a capital. When the fillet is at the top or bottom of the shaft of a column it is called a cincture. Palladio uses the word orle to express the plinth of the bases of the columns and pedes

Ornament. The smaller and detailed part of the work, not essential to it, but serving to enrich it; it is generally founded upon some imitation of the works of nature.

Orthography. (Gr. Ορθος, right, and Γραφω, I describe.) The elevation of building showing all the parts in their proper proportions; it is either external or internal. The first is the representation of the external part or front of a building showing the face of the principal wall, with its apertures, roof of the building, projections, decorations, and all other matters as seen by the eye of the spectator, placed at an infinite distance from it. The second, commonly called the *section* of a building, shows it as if the external wall were removed, and separated from it.

In geometry, orthography is the art of representing the plan or side of any object, and of the elevation also of the principal parts: the art is so denominated from its etymology, because it determines things by perpendicular *right lines* falling on the geometrical plan, or because all the horizontal lines are straight and parallel, and not, as in perspective, oblique.

Osculating Circle. That, the radius of whose curve at any particular point of another curve, is of the same length as that of the curve in question at that particular point. Hence it is the kissing circle, and that so closely, that there is no difference in the curvature of the two curves at that particular point.

Ova. (Lat.) Ornaments in the shape of an egg, into which the echinus or ovolo is often carved.

Oval. A geometrical figure, whose boundary is a curve line returning into itself; it includes the ellipsis or mathematical oval, and all figures resembling it, though with different properties.

Ovolo. (Ital.) A convex moulding whose lower extremity recedes from a perpendicular line drawn from the upper extremity. See Moulding.

Out to Out. An expression used of any dimension when measured to the utmost bounds of a body or figure.

Out of Winding. A term used by artificers to signify that the surface of a body is that of a perfect plane; thus when two straight edges are in the same plane they are said to be out of winding.

Outer Doors. Those common to both the exterior and interior sides of a building

Outer Plate. See Inner Plate.

Outline. The line which bounds the contour of any object.

Outward Angle. The external or salient angle of any figure.

Overhang. See Batter.

P.

Paddle. A small sluice, similar to that whereby water is let into or out of a canal lock.

Pagoda. (Corrupted from Poutgad, Pers., a house of idols.) A name given to the temples of India. See Indian Architecture. Book I. Chap. II. Sect. 6.

Paine. See Architects, list of, 303.

Painter's Work. See Book II. Chap. III. Sect. 12.

The work of painting with different coats of oil colour and turpentine the parts of a building usually so treated.

Palace. (Lat. Palatium.) In this country, a name given to the dwelling of a king or queen, a prince, and a bishop. On the Continent, it is a term more extensively used, almost all large dwellings and government offices being so denominated. See Book III. Chap. III. Sect. 4.

Palados. (Gr.) The grand entrance of the scene of an ancient theatre that conducted on to the stage and orchestra.

Palæstra. (Gr. Παλαιω, I wrestle.) A part of the Grecian gymnasium, particularly appropriated to wrestling and other gymnastic exercises; it was sometimes used to denote the whole building. It contained baths which were open for the use of the public. According to the authority of Vitruvius, no palæstra existed in Rome.

Pale. A small pointed stake or piece of wood used for making landmarks and enclosures placed vertically.

Pale Fencing or **Pale Fence.** That constructed with pales.

Palisade. A fence of pales or stakes driven into the ground, set up for an enclosure, or for the protection of property.

Palladio. See Architects, list of, 241.

Palm. A measure of length. See Measure.

Pampre. (Fr.) An ornament composed of vine leaves and bunches of grapes, wherewith the hollow of the circumvolutions of twisted columns are sometimes decorated.

Pancarpi. (Gr.) Garlands and festoons of fruit, flowers, and leaves, for the ornament of altars, doors, vestibules, &c.

Panel. (From the low Latin panellum.) A board whose edges are inserted into the groove of a thicker surrounding frame.

A panel in masonry is one of the faces of a hewn stone.

Pannier. The same as Corbel, which see.

Pantameter. A graduated bevel.

Pantiles. See Book II. Chap. II. Sect. 9.

Pantograph. An instrument for copying, diminishing, or enlarging drawings.

Paper. A substance made by the maceration of linen rags in water and spreading them into thin sheets; on this the drawings of the architect are usually made; its usual sizes being as under: —

Demy	- -	20 inches by	15 inches.		Atlas	- - -	34 inches by	26 inches.
Medium	- -	22 —	17 —		Double Elephant	-	40 —	26 —
Royal	- -	24 —	19 —		Antiquarian	- -	52 —	31 —
Super-royal	-	27 —	19 —		Extra Antiquarian		56 —	40 —
Imperial	- -	30 —	21 —		Emperor	- -	68 —	48 —
Colombier	- -	34 —	23 —					

Paperhanger's Work. See Book II. Chap. III. Sect. 12.

Parabola. (Gr. Παρα, through, and Βαλλω, I throw.) In geometry, a curve line formed by the common intersection of a conic surface, and a plane cutting it parallel to another plane touching the conic surface. See Book II. Chap. I. Sect. 5.

Parabolic Assymptote. In geometry, a line continually approaching the curve, but which, though infinitely produced, will never meet it.

Parabolic Curve. The curved boundary of a parabola, and terminating its area, except at the double ordinate.

Parabolic Spiral, or **Helicoid.** A curve arising from the supposition of the axis of the common parabola bent into the periphery of a circle, the ordinates being portions of the radii next the circumference.

Paraboloid. See Conoid.

Parallel. (Gr. Παραλληλος.) In geometry, a term applied to lines, surfaces, &c., that are in every part equidistant from each other.

Parallel Coping. See Coping.

Parallelogram. (Gr.) Any four-sided rectilineal figure, whose opposite sides are parallel.

Parallelopiped. In geometry, one of the regular bodies or solids comprehended under six faces, each parallel to its opposite face, and all the faces parallelograms.

Parameter. (Gr. Παρα, through, and Μετρω, I measure.) In conic sections, a constant right line in each of the three sections, called also *latus rectum*.

Parapet. (Ital. Parapetto, breast high.) A small wall of any material for protection on the sides of bridges, quays, or high buildings.

Parascenium. Another name for the *postscenium* in the ancient theatre.

Parastatæ. See Antæ.

Parget. A name given to the rough plaster used for lining chimney flues.

Parker's Cement. See p. 509.

Parlour. (Fr.) A room for conversation, which in the old monasteries adjoined the buttery and pantry at the lower end of the hall. At the present day it is used to denote the room in a house where common visitors are received.

Parquetry. See Marquetry.

Parsonage House. A building usually near the church, occupied by the incumbent of the living; in former times this sort of building was often embattled and fortified, and had various appendages, including sometimes a small chapel or oratory.

Partition. (Lat.) A wall of stone, brick, or timber, dividing one room from another; when a partition has no support from below it should not be suffered to bear on the floor with any considerable weight, and in such cases it should have a *truss* formed within, in which case it is called a *trussed partition*. See Truss.

Party Walls. Such as are formed between houses to separate them from each other and prevent the spreading of fire. The regulations prescribed for them form a large portion of the Building Act of 14 Geo. III. See Building Act at length, p. 819, *et seq.*

Party Fence Wall. A wall separating the vacant ground in one occupation from that in another. See Building Act, p. 819, *et seq.*

Parvis. (Etym. uncertain.) A porch portico or large entrance to a church. It seems also to have signified a room over the church porch, where schools used to be held.

Passages. The avenues leading to the various divisions and apartments of a building. When there is only one series of rooms in breadth, the passage must run along one side of the building, and may be lighted by apertures through the exterior walls. If there be more than one room in breadth, it must run in the middle, and be lighted from above or at one or both ends.

Patera. (Lat.) A vessel used in the Roman sacrifices, wherein the blood of the victims was received. It was generally shallow, flat, and circular. Its representation has been introduced as an ornament in friezes and fasciæ, accompanied with festoons of flowers or husks, and other accessories.

Paternosters. A species of ornament in the shape of beads, either round or oval, used in baguettes, astragals, &c.

Pautre, le. See Architects, list of, 261.

Pavement. (Lat. Pavimentum.) A path or road laid or beaten in with stones or other materials. According to the information of Isidorus, the first people who paved their streets with stone were the Carthaginians. Appius Claudius, the founder of the Appian Way, appears to have introduced the practice into Rome, after which the Roman roads were universally paved, remains of them having been found in every part of the empire.

In the interior of the Roman houses, the pavement was often laid upon timber framing; and the assemblages so constructed were called *contignata pavimenta.* The pavement called *coassatio* was made of oaken planks of the *quercus esculus,* which was least liable to warp. The Roman pavements were also frequently of mosaic work, that is, of square pieces of stone, called tesseræ, in various patterns and figures, many of which remain in Britain to the present day.

The various sorts of paving are as follows: — 1. *Pebble paving,* of stones collected from the sea beach, mostly obtained from Guernsey or Jersey. This is very durable if well laid. The stones vary in size, but those from six to nine inches deep are the best. Those of three inches in depth are called *bolders* or *bowlers,* and are used for paving court-yards and those places where over-heavy weights do not pass. 2. *Rag paving:* inferior to the last, and usually from the vicinity of Maidstone, in Kent, whence it bears the name of Kentish rag stone. It is sometimes squared, and then used for paving coach-tracks and footways. 3. *Purbeck pitchers,* which are square stones, used in footways, brought from the island of Purbeck. They are useful in court-yards: the pieces running about five inches thick, and from six to ten inches square. 4. *Squared paving,* by some called *Scotch paving,* of a clear close stone, called *blue wynn.* This is now, however, quite out of use. 5. *Granite,* of the material which its name imports. 6. *Guernsey paving,* which, for street work, is the best in use. It is broken with iron hammers, and squared to any required dimensions, of a prismoidal figure, with a smaller base downwards. It is commonly bedded in small gravel. 7. *Purbeck paving,* used for footways, of which the blue sort is the best, is obtained in pretty large surfaces, of about two inches and a half thick. 8. *Yorkshire paving:* a very good material, and procurable of very large dimensions. 9. *Ryegate* or *fire-stone paving,* used for hearths, stoves, ovens, and other places subject to great heat, by which this stone, if kept dry, is not affected. 10. *Newcastle flags,* useful for the paving of offices. They run about one and a half to two inches thick, and about two feet square, and bear considerable resemblance to the Yorkshire. 11. *Portland paving* may be had from the island of Portland of almost any required dimensions. The squares are sometimes ornamented by cutting away their angles, and inserting small black marble squares, set diagonally. 12. *Sweedland paving:* a black slate dug in Leicestershire, useful for paving halls or for party-coloured paving. 13. *Marble paving,* of as many sorts almost as there are species of marble. It is sometimes inlaid after the manner of Mosaic work. 14. *Flat brick paving,* executed with bricks laid flat in sand, mortar, or grout, when liquid lime is poured into the joints. 15. *Brick* or *edge paving,* executed in the manner of the last, except that the bricks are laid on edge. 16. *Herring-bone paving:* bricks laid diagonally to each other. See Herring-bone Work. 17. *Bricks laid endwise* in sand, mortar, or grout. 18, *Paving bricks,* are made especially for the purpose, and are better than stocks. 19. *Ten-inch tile* paving. 20. *Foot tile paving.* 21. *Clinker paving.*

The pavements of churches are often in patterns of several colours, of which, to shew the great variety that may be obtained from a few colours, M. Truchet (*Mém. Acad. Fran.*) has proved that two square stones, divided diagonally into two colours, may be joined together chequerwise in sixty-four different ways.

PAVEMENT (DIAMOND). That in which the stones, flags, or bricks are laid with their diagonals perpendicular to the sides of the apartment.

PAVILION. (Ital. Padiglione.) A turret or small building, generally insulated and comprised under a single roof. The term is also applied to the projecting parts in the front of a building. Sometimes, as at the Louvre, they are placed on the flanks of the building. They are usually higher than the rest of the building.

PEDESTAL. (Compound, apparently, of Pes, a foot, and Στυλος, a column.) The lowest division in an order of columns, called also *stylobates* and *stereobates*. The pedestal consists of three principal parts: the die or square trunk, the cornice or head, and the base or foot. See Book III. Chap. I. Sect. 8.

PEDIMENT. The triangular crowning part of a portico or aperture, which terminates vertically the sloping parts of the roof. In Gothic architecture, this triangular piece is much higher in proportion to its width, and is denominated a gable. The subject of pediments is fully treated of in Book III. Chap. I. Sect. 17.

PELASGIC ARCHITECTURE. See Book I. Chap. II. Sect. 2.

PENDENT. (Lat.) An ornament suspended from the summit of Gothic vaulting, very often elaborately decorated. Of this ornament, there are some beautiful examples in Henry VII.'s chapel. The pendent was also used very frequently to timber-framed roofs, as in that of Crosby Hall, which has a series of pendents along the centre of it. Pendents are also attached to the ends of the hammer beams in Gothic timber roofs.

PENDENTIVE. The entire body of a vault suspended out of the perpendicular of the walls, and bearing against the arch boutants, or supporters. It is defined by Daviler to be the portion of a vault between the arches of a dome, commonly enriched with sculpture. Felibien defines it as the plane of the vault contained between the double arches, the forming arches, and the ogives. See p. 560.

PENDENTIVE BRACKETING or **CAVE BRACKETING.** That springing from the rectangular walls of an apartment upwards to the ceiling, and forming the horizontal part of the ceiling into a circle or ellipsis.

PENDENTIVE CRADLING. The timber work for sustaining the lath and plaster in vaulted ceilings.

PENETRALE. (Lat.) The most sacred part of the temple, which generally contained an altar to Jupiter Herceus, which appellation, according to Festus, was derived from ἑρκος, an enclosure, and supposed him the protector of its sanctity.

PENETRALIA. (Lat.) Small chapels dedicated to the Penates, in the innermost part of the Roman houses. In these it was the custom to deposit what the family considered most valuable.

PENITENTIARY. In monastic establishments was a small square building, in which a penitent confined himself. The term was also applied to that part of a church to which penitents were admitted during divine service. The word, as used in the present time, implies a place for the reception of criminals whose crimes are not so heinous as to deserve punishment beyond that of solitary confinement and hard labour, and where means are used to reclaim as much as possible those who have become subject to the laws by transgressing them. See PRISON, Book III. Chap. III. Sect. 18.

PENSTOCK. A small paddle, working up vertically in a grooved frame, and for penning back water.

PENTADORON. (Gr.) A species of brick used in ancient architecture, which was five palms long.

PENTAGON. (Gr. Πεντε, five, and Γωνια, an angle.) In geometry, a figure of five sides and five angles. When the five sides are equal, the angles are too, and the figure is called a regular pentagon.

PENTAGRAPH. See PANTOGRAPH.

PERIACTI. (Gr. Περιαγειν, to revolve.) The revolving scenes in an ancient theatre, called by the Romans *scenæ versatiles*.

PERIBOLUS. (Gr.) A court or enclosure within a wall, sometimes surrounding a temple. It was frequently ornamented with statues, altars, and monuments, and sometimes contained other smaller temples or a sacred grove. The peribolus of the temple of Jupiter Olympius, at Athens, was four stadia in circumference. That of the temple of Apollo Dindymæus, near Miletus, was also of some extent.

PERCIER. See ARCHITECTS, list of, 317.

PERCY. See ARCHITECTS, list of, 184.

PEREZ. See ARCHITECTS, list of, 126.

PERIDROME. (Gr. Περι, about, Δρομος, a course.) The space, in ancient architecture, between the columns of a temple and the walls enclosing the cell.

PERIMETER. (Gr.) The boundary of a figure.

PERIPHERY. (Gr. Περιφερω, I surround.) The circumference of a circle, ellipsis, parabola, or other regular curvilinear figure.

PERIPTERY. (Gr.) The range of insulated columns round the cell of a temple.

Peripteral. (Gr.) A temple surrounded by a periptery, that is, encompassed by columns. See Temple.

Peristylium. (Gr.) In Greek and Roman buildings, a court, square or cloister, which sometimes had a colonnade on three sides only, and therefore in that case improperly so called. Some peristylia had a colonnade on each of the four sides; that on the south being sometimes higher than the rest, in which case it was called a *Rhodian peristylium*. The range of columns itself was called the *peristyle*. See Colonnade.

Peritherides. The same as Ancones, which see.

Peritrochium. (Gr.) A term in mechanics applied to a wheel or circle concentric with the base of a cylinder, and together with it moveable about an axis.

Perpendicular. In geometry, a term applied to a right line falling directly on another line, so as to make equal angles on each side, called also a *normal line*. The same definition will hold of planes standing the one on the other. A perpendicular to a curve is a right line cutting the curve in a point where another right line to which it is perpendicular makes a tangent with the curve.

Perpend Stone or **Perpender.** A long stone reaching through the thickness of the wall, so as to be visible on both sides, and therefore wrought and smoothed at the ends.

Perrault. See Architects, list of, 259.

Perron. A French term, denoting a staircase, lying open or without side the building; or more properly the steps in the front of a building which lead into the first story, where it is raised a little above the level of the ground.

Perronet. See Architects, list of, 298.

Persian or **Persepolitan Architecture.** See Book I. Chap. II. Sect. 4.

Persians. See Caryatides.

Perspective. (Lat. Perspicio.) The science which teaches the art of representing objects on a definite surface, so as from a certain position to affect the eye in the same manner as the objects themselves would. This art forms the subject of Book II. Chap. IV. Sect. 2.

Peruzzi. See Architects, list of, 200.

Pest House. A lazaretto or infirmary where persons, goods, &c., infected with the plague or other contagious disease, or suspected so to be, are lodged to prevent communication with others, and the consequent spread of the contagion.

Peter of Colechuch. See Architects, list of, 106.

Phæax. See Architects, list of, 28.

Phalangæ. (Gr.) A name applied by Vitruvius to a species of wooden rollers, used to transport heavy masses from one spot to another.

Pharos. (Gr. from Φως, a light, and Οραω, I see.) The name applied to an ancient lighthouse. See Book III. Chap. III. Sect. 12.

Pheasantry. A building or place for the purpose of breeding, rearing, and keeping pheasants.

Philo. See Architects, list of, 26.

Phonics. The doctrine of sounds, which has not yet been so reduced in its application to architecture as to have justified in this work more than its definition in this place. See the Sect. 16. Chap. III. Book III. on Theatres.

Photometer. (Gr.) An instrument for measuring the different intensities of light.

Piazza. (Ital.) A square open space surrounded by buildings. The term is very frequently and very ignorantly used to denote a walk under an arcade.

Piedroit. (Fr.) A French term, signifying a pier or square pillar, partly hid within a wall. It differs from a pilaster in having neither base nor capital.

Pier. (Fr.) A solid between the doors or windows of a building. The square or other formed mass or post to which a gate is hung. Also the solid support from which an arch springs. In a bridge, the pier next the shore is usually called an abutment pier.

Pietro di Gamiel. See Architects, list of, 195.

Pietro San. See Architects, list of, 119.

Pilaster. (Fr.) A sort of square column, sometimes insulated, but more commonly engaged in a wall, and projecting only a fourth or fifth of its thickness. See Book III. Chap. I. Sect. 14.

Piles. (Lat.) Large timbers driven into the earth, upon whose heads is laid the foundation of a building in marshy and loose soils. Amsterdam and some other cities are built wholly upon piles. The stoppage of Dagenham Breach was effected by piles mortised into one another by dovetail joints. They are best and most firmly driven by repeated strokes; but for the saving of time, a pile engine is generally used, in appearance and effect very much like a guillotine, which, having raised the *monkey* or hammer to a certain height, lets it, by pressing the clasps which carry it up, suddenly drop down on the pile to be driven.

Pillar. (Fr. Pilier.) A column of irregular form, always disengaged, and always deviating from the proportions of the orders, whence the distinction between a column and a pillar. In any other sense it is improperly used.

Pin. In carpentry, a cylindrical piece of wood driven to connect pieces of framing together.

Pinnacle. (Low Lat. Pinnaculum.) A summit or apex. The term is usually applied to the ornament in Gothic architecture placed on the top of a buttress, or as the termination to the angle of the gable of a building. It is also placed on different parts of a parapet, at the sides of niches, and in other situations. Its form is usually slender, and tapers to a point.

Pinning up. In underpinning the driving the wedges under the upper work so as to bring it fully to bear upon the work below.

The term pinning is also used to denote the fastening of tiles together with pins or pieces of heart of oak in the covering of buildings.

Pino, di. See Architects, list of, 201.

Pintelli. See Architects, list of, 155.

Pipe. A conveyance for water or soil from any part of a building, usually of lead or iron. When for the supply of water to a building it is called a *service pipe;* when for carrying off water, a *waste pipe;* and when for carrying off soil, a *soil pipe;* and those which carry away the rain from a building are called *rain-water pipes.* When a cistern or reservoir is supplied in such a way that those who labour to fill it should be made aware that it is full, the pipe which discharges the overflow is called a *warning pipe.*

Pippi. See Architects, list of, 218.

Piscina. (Lat.) Among the Romans this term was applied to a fish-pond, to a shallow reservoir for practising swimming, and to a place for watering horses and washing clothes. The piscina in ecclesiastical architecture was a bowl for water, generally in a niche in the wall of the church wherein the priest laved his hands. There was usually one attached to every altar for the priest to wash his hands on the performance of the sacred rites. The variety of their form is great; some were extremely simple, others very richly decorated.

Pisé. A species of walling, of latter years used in France, made of stiff earth or clay rammed in between moulds as it is carried up. This method of walling was however in very early use. (*Plin.* lib. xxxiv. chap. 14.)

Pit of a Theatre. The part on the ground-floor between the lower range of boxes and the stage.

Pitch. A term generally applied to the vertical angles formed by the inclined sides of a roof.

Pitching Piece. In staircasing, an horizontal piece of timber, having one of its ends wedged into the wall at the upper part of a flight of steps, to support the upper ends of the *rough strings.* See Apron Piece.

Pivot. (Fr.) The sharpened point upon which a perpendicular wheel performs its revolutions.

Place Bricks. See p. 504.

Plafond or Platfond. (Fr.) The ceiling of a room, whether flat or arched; also the under-side of the projection of the larmier of the cornice; generally any sofite.

Plain or Plane Angle. One contained under two lines and surfaces, so called to distinguish it from a solid angle.

Plain Tiles, properly **Plane Tiles.** Those whose surfaces are planes. See Book II. Chap. II. Sect. 9.

Plan. (Fr.) The representation of the horizontal section of a building, showing its distribution, the form and extent of its various parts. In the plans made by the architect, it is customary to distinguish the massive parts, such as walls, by a dark colour, so as to separate them from the voids or open spaces. In a *geometrical plan,* which is that above mentioned, the parts are represented in their natural proportions. A *perspective plan* is drawn according to the rules of perspective. The *raised plan* of a building is the elevation of it.

Plancher. The same as the sofite or under-surface of the corona; the word is however very often used generally to mean any sofite.

Plane. (Lat. Planus.) A tool used by artificers that work in wood for the purpose of producing thereon a flat even surface. There are various sorts of planes, whose description will be found at p. 564.

Plane. In geometry, a surface that coincides in every direction with a straight line.

Plane, geometrical. In perspective, a plane parallel to the horizon, whereon the object to be delineated is supposed to be placed. It is usually at right angles with the perspective plane.

Plane, horizontal. In perspective, a plane passing through the spectator's eye, parallel to the horizon, and cutting the perspective plane in a straight line, called the *horizontal line.*

Plane, inclined. One that makes an oblique angle with a horizontal plane.

Plane, objective. Any plane, face, or side of an original object to be delineated on the perspective plane.

Plane, perspective. That interposed between the original objects and the eye of the spectator, and whereon the objects are to be delineated.

Plane Trigonometry. See Book II. Chap. I. Sect. 4.

Planimetry. That branch of geometry which treats of lines and surfaces only, without reference to their height or depth.

Plank. (Fr.) A name given generally to all timber, except fir, which is less than four inches thick and thicker than one inch and a half. See Board.

Plaster and Plasterer's Work. See Book II. Chap. III. Sect. 9.

Plaster of Paris. A preparation of gypsum, originally procured in the vicinity of Mont Martre near Paris. The plaster stone, or alabaster, is, however, found in many parts of England, as at Chelaston near Derby, and Beacon Hill near Newark. The former pits yield about 800 tons a year. It is ground and frequently used for manure, or rather as a stimulant for grass. It is calcined into the plaster used by the modeller, plasterer, &c. When diluted with water into a thin paste, plaster of Paris sets rapidly, and at the instant of setting, its bulk is increased. Mr. Boyle found by experiment that a glass vessel filled with this paste, and close stopped, bursts while the mixture sets, a quantity of water sometimes issuing through the cracks; hence this material becomes valuable for filling cavities, &c., when other earths would shrink. The gypsum is prepared either by burning or boiling, and loses from four to six cwt. in a ton. After burning, it is ground into powder in a mill.

Platband. Any flat and square moulding whose projection is much less than its height, such are the fasciæ of an architrave, the list between flutings, &c. The platband of a door or window is the lintel, when it is made square and not much arched.

Plate. A general term applied to those horizontal pieces of timber lying mostly on walls for the reception of another assemblage of timbers. Thus, a *wall plate* is laid round the walls of a building to receive the timbering of a floor and roof; a *gutter plate* under the gutter of a building, &c.

Plate Glass. See Glass.

Plate Rack. A fixture over the sink in a scullery for the reception of dinner plates and dishes after washing.

Platform. An assemblage of timbers for carrying a flat covering of a house, or the flat covering itself. A terrace or open walk at the top of a building.

Plinth. (Gr. Πλίνθος, a brick.) The lower square member of a base of a column or pedestal. In a wall the term *plinth* is applied to two or three rows of bricks which project from the face.

Plotting. The art of laying down on paper the angles and lines of a plot of land by any instrument used in surveying.

Plug. A piece of timber driven perpendicularly into a wall with the projecting part sawn away, so as to be flush with the face.

Plug and Feather, or Key and Feather. A name given to a method of dividing hard stones by means of a long tapering wedge, called the *key*, and wedge-shaped pieces of iron called *feathers*, which are driven into holes previously drilled into the rock for the purpose, and thus forcibly split it.

Plumbing. (Lat. Plumbus.) The art of casting and working in lead and using it in building. See Book II. Chap. III. Sect. 7.

Plumb Rule, Plumb Line, or Plummet. An instrument used by masons, carpenters, &c., to draw perpendiculars or verticals, for ascertaining whether their work be upright, horizontal, and so on. The instrument is little more than a piece of lead or plummet at the end of a string, sometimes descending along a wooden or metal ruler raised perpendicularly on another, and then it is called a level. See Level.

Podium. (Lat.) A continued pedestal. A projection which surrounded the arena of the ancient amphitheatre. See Amphitheatre.

Point. (Lat. Punctum.) In geometry, according to Euclid, that which has neither length, breadth, nor thickness.

Point, accidental. In perspective, a term used by the old writers on the science to signify the vanishing point.

Point of Distance. In perspective, the distance of the picture transferred upon the vanishing line from the centre, or from the point where the principal ray meets it, whence it is generally understood to be on the vanishing line of the horizon. See Distance.

Point, objective. A point on a geometrical plane whose representation is required on the perspective plane.

Point of Sight. The place of the eye whence the picture is viewed, according to Dr. Brook Taylor, but, according to the old writers on perspective, is what is now called the centre of the picture.

Point of View. The point of sight.

Pointed Arch. See p. 119, *et seq.*

Pointed Architecture. See Book I. Chap. II. Sect. 15.

Pointing. The raking out the mortar from between the joints of brickwork, and replacing the same with new mortar.

Points of Support. The points or surfaces on which a building rests. See p. 438.

Polishing. See Marble.

Pollajolo. See Architects, list of, 179.

Pollard. A tree which has been frequently lopped or *polled* of its head and branches, a practice very injurious to good timber.

Polygon. (Gr. Πολυς, many, and Γωνια, an angle.) A multilateral figure, or one whose perimeter consists of more than four sides and angles. If the sides and angles be equal the figure is called a regular polygon. Polygons are distinguished according to the number of the sides; thus those of five sides are called *pentagons*, those of six, *hexagons*, those of seven, *heptagons*, and so on. The subjoined is a table of the areas and perpendiculars of polygons the side being =1.

Number of Sides.	Names of Polygons.	Area.	Perpendiculars.
3	Trigon - -	·433013	·2886751
4	Tetragon -	1·000000	·5000000
5	Pentagon -	1·720477	·6881910
6	Hexagon -	2.598076	·8660254
7	Heptagon -	3·633912	1·0382617
8	Octagon -	4·828427	1·2071068
9	Enneagon -	6·181824	1·3737387
10	Decagon -	7·694209	1·5388418
11	Endecagon -	9·365640	1·7028437
12	Dodecagon -	11·196152	1·8660254

From the above to find the area of a regular polygon, multiply one of the sides of the polygon by the perpendicular from the centre on that side, and multiply half the product by the number of sides; or, multiply the square of the given side of the polygon by the number opposite to its name under the word area.

Polygram. (Gr.) A figure consisting of many lines.

Polyhædron. (Gr.) A solid contained under many sides or planes. If the sides of a polyhædron be regular polygons, all similar and equal, it becomes a regular body, and may be inscribed in a sphere, that is, a sphere may be drawn round it, so that its surface shall touch all the solid angles of the body.

Polystyle. (Gr. Πολυς and Στυλος.) Of many columns. See Colonnade.

Pomel. (Lat. Pomum.) A globular protuberance terminating a pinnacle, &c.

Pontoon. (Fr.) A bridge of boats.

Poore. See Architects, list of, 112.

Poplar. (Lat. Populus.) A tree sometimes used in building. See p. 486.

Porch. (Fr.) An exterior appendage to a building, forming a covered approach to one of its principal doorways.

Porphyry. (Gr.) A very hard stone, partaking of the nature of granite. It is not so fine as many of the ordinary marbles, but far exceeds them in hardness, and will take a very fine polish. It is still found in Egypt in immense strata. It is generally of a high purple, which varies, however, from claret colour to violet. Its variations are rarely disposed in grains. The red lead coloured porphyry, which abounds in Minorca, is variegated with black, white, and green, and is a beautiful and valuable material. The pale and red porphyry, variegated with black, white, and green, is found in Arabia Petræa and Upper Egypt, and in separate nodules in Germany, England, and Ireland. The sorts best known are what the Italians call the *porfido rosso* (red), which is of a deep red with oblong white spots; the latter are of *feld spath*, which resembles *schorl*. There are two varieties of black porphyry, the *porfido nero*, or black porphyry, and that called the *serpentino nero antico*. The first has a ground entirely black, spotted with oblong white spots like the red porphyry; the other has also a black ground with great white spots, oblong, or rather in the form of a parallelopipedon, nearly resembling in colour what the French call *serpentin vert antique*. The *brown porphyry* has a brown ground with large oblong greenish spots. There are several sorts of green porphyry, which the Italians principally distinguish by the names of *serpentino antico verde*, found in great abundance and in large blocks in the neighbourhood of the ancient Ostia, of a green ground with oblong spots of a lighter shade of the same colour; and the *porfido verde*, which is of a ground of very dark green, almost approaching to black, with lighter shades of a fine grass green. The art of cutting porphyry, as practised by the ancients, appears to be now quite lost.

Portal. (Fr. Portail, from Lat. Porta.) The arch over a door or gate; the framework of the gate; the lesser gate, when there are two of different dimensions at one entrance. This term was formerly applied to a small square corner in a room separated from the rest of the apartment by wainscotting.

Portcullis. (Fr.) A strong grated framing of timber, resembling a harrow, the vertical pieces whereof were pointed with iron at the bottom, for the purpose of striking into the ground when it was dropped, and also to break and destroy that upon which it fell. It was made to slide up and down in a groove of solid stone-work within the arch of the portals of old castles. Its introduction is supposed to have been in the early Norman castles.

Portico. (Lat. Porticus.) See Colonnade.

Portland Stone. A dull white species of stone brought from the island of Portland. See p. 468, *et seq.*

Portuguese Architecture. See Book I. Chap. II. Sect. 19.

Position. In geometry, the situation of one thing in regard to another. Speaking architecturally, it is the situation of a building in respect of the four cardinal points of the horizon.

Post. (Fr.) An upright piece of timber set in the earth. Any piece of timber whose office is to support or sustain in a vertical direction, as the *king* and *queen posts* in a roof, is so called.

Post and Paling. A close wooden fence constructed with posts fixed in the ground and pales nailed between them. This kind of fence is sometimes called *post and railing*, though this latter is rather a kind of open wooden fence, used for the protection of young quickset hedges, consisting of posts and rails, &c.

Posticum. (Lat.) See Cell.

Postscenium or Parascenium. (Lat.) In ancient architecture, the back part of the theatre, where the machinery was deposited, and where the actors retired to robe themselves.

Postumius, C. See Architects, list of, 37.

Poultry House. A building for the shelter and rearing of poultry, whereof, perhaps, the finest example is that at Winnington in Cheshire. The front is one hundred and forty feet in length, with a pavilion at each end, united to the centre by a colonnade of small cast-iron pillars, supporting a slated roof, which shelters a paved walk. In the centre of the front are four strong columns, and as many pilasters, supporting a slated roof, with an iron gate between them, from which a large semicircular court is entered, with a colonnade round it, and places for the poultry. On one side of the gate is a small parlour, and at the other end of the colonnade a kitchen.

Power. In mechanics, a force which, applied to a machine, tends to produce motion. If it actually produce it, it is called a *moving power*, if not, it is called a *sustaining power*. The term is also used in respect of the six simple machines, viz. the *lever*, the *balance*, the *screw*, the *axis in peritrochio*, the *wedge*, and the *pulley*, which are called the *mechanical powers*.

Pozzo, Del. See Architects, list of, 157.

Pozzolano. See Puzzolano.

Præcinctio (Lat.) or **Balteus.** A wide seat, or rather step, round the audience part of the ancient theatres and amphitheatres. It was termed διαζωμα by the Greeks.

Preaching Cross. A cross erected in the highway, at which the monks and others preached to the public.

Preceptory. A manor or estate of the knights templars, on which a church was erected for religious service, and a convenient house for habitation, and generally placed under one of the more eminent members of the fraternity, called the *præceptores templi*, to have care of the lands and rents of the place. The preceptories were nothing more than cells to the temple, or principal house of the knights in London.

Presbytery. That part of the church reserved for the officiating priests, comprising the choir and other eastern parts of the edifice.

Preserving Timber. See p. 489.

Prices of Work. See p. 620, *et seq.*

Prick Post. The same as Queen Post.

Prime. (Lat.) A figure in geometry that cannot be divided into any other figures more simple than itself, as a triangle in plane figures, and a pyramid in solids.

A *prime number* is one that cannot be divided by another number without a remainder.

Priming. In painter's work, the first colouring of the work, which forms a ground for the succeeding coats.

Principal Brace. One immediately under the principal rafters, or parallel to them, in a state of compression, assisting, with the principals, to support the timbers of the roof.

Principal Point. In perspective, a point in the perspective plane upon which a line will fall drawn from the eye perpendicular to that plane. The principal point is, in fact, the intersection of the horizontal and vertical planes, or the *point of sight*, or *of the eye*.

Principal Rafters. Those whose sizes are larger than the common rafters, and framed in such a manner as to bear the principal weight of the others. See p. 548.

Principal Ray. In perspective, the line passing from the eye to the principal point on the perspective plane.

Priory. A building similar in its constitution to a monastery or abbey, the head whereof was called a prior or prioress.

Prism. (Gr. Πρισμα.) In geometry, an oblong or solid body contained under more than four planes, whose bases are equal, parallel, and similarly situate.

Prismoid. A solid figure, having for its two ends any dissimilar parallel plane figure of the same number of sides, and all the upright sides of the solid trapezoids. If the ends of the prismoid be bounded by dissimilar curves, it is sometimes called a *cylindroid*.

Prison. A building erected for the confinement, or safe custody, of those who have transgressed the laws of their country, until, in due course of time, they are discharged. See Book III. Chap. III. Sect. 18.

Private Buildings. See Book III. Chap. III. Sects. 20, 21, 22.

Problem. (Gr.) In geometry, a proposition in which some operation or construction is required, as to divide a line, to make an angle, to draw a circle through three points not in a right line, &c. A problem consists of three parts: the proposition, which states what is required to be done; the resolution or solution, wherein are rehearsed the step or steps by which it is done; and the demonstration, wherein it is shown that by doing the several things prescribed in the resolution the thing required is obtained.

Prodomus. In ancient architecture, the portico before the entrance to the cell of a temple. See Cell.

Producing. In geometry, the continuing a right line to any required length.

Profile. The vertical section of a body. It is principally used in its architectural sense to signify the contour of architectural members, as of bases, cornices, &c. The profile of an order is in fact the outline of the whole and its parts, the drawing whereof is technically called profiling the order. *Profiles of doors* are given in Book III. Chap. I. Sect. 19.

Projection. The art of representing a body on a plane by drawing straight lines through a given point, or parallel from the contour and from the intermediate lines of the body, if any, so as to cut the plane. When the projection is made by drawing straight lines from a point, it is called a *perspective representation;* but if formed by parallel lines, it is called an *orthographical representation*. See Perspective, in Book II. Chap. V. Sect. 2., and Descriptive Geometry, Book II. Chap. I. Sect. 6. For the method of projecting shadows, see Book II. Chap. IV. Sect. 3.

Projecture. An out-jetting or prominence beyond the naked of a wall, column, &c. By the Greeks projectures were called *εκφοραι*, by the Italians *sporti*, by the French *saillés;* so our workmen called them *sailings over*.

Prolate. (Lat.) An epithet applied to a spheroid when generated by the revolution of a semi-ellipsis about its longer diameter.

Pronaos. See Cell.

Proportion. The just magnitude of each part, and of each part to another, so as to be suitable to the end in view. For the proportions of the several parts of a building, the reader is referred to Book III. Chap. I., wherein they are considered at length.

Proportional Compasses. See Compasses.

Proportions of Rooms. See Book III. Chap. I. Sect. 25.

Propylæum. (Gr. Προ, before, and Πυλη, a portal.) Any court or vestibule before a building, or before its principal part; but more particularly the entrance to such court or vestibule.

Proscenium. (Gr.) That part in the ancient theatre whereon the actors performed in front of the scene, being what we call the stage. The Romans called this part the *pulpitum*.

Prostyle. (Gr. Προ, and Στυλος, a column.) A portico in which the columns stand in advance of the building to which they belong.

Prothyris. (Gr.) A word used in ancient architecture to signify a cross beam or overthwart rafter, as likewise a quoin or course of a wall. See Console.

Prothyrum. (Gr.) A porch at the outer door of a house; a portal.

Protractor. (Lat. Protractus.) An instrument for laying down an angle in drawing or plotting.

Pseudisodomum. See Isodomum.

Pseudodipteral or False Dipteral. A disposition in the temples of antiquity wherein there were eight columns in front and only one range round the cell. It is called false or imperfect, because the cell only occupying the width of four columns, the sides from the columns to the walls of the cell have no columns therein, though the front and rear present a column in the middle of the void. See Temple.

Pseudoperipteral or Imperfect Peripteral. A disposition in the ancient temples, in which the columns on the sides were engaged in the wall, and wherein there was no portico except to the façade in front; such are the Maison Carrée at Nismes, and the temple of Fortuna Virilis at Rome.

Ptera. See Aisles.

Pteroma. (Gr. Πτερον, a wing.) The space between the wall of the cell of a temple and the columns of the peristyle, called also *ambulatio*.

Puddling. The filling behind a wall, filling up a cavity, or banking up with clay tempered with water, and carefully rammed down with the repeated strokes of beaters or beetles.

Pugging. A coarse kind of mortar laid upon the sound boarding between joists, to prevent the transmission of sound from the apartment above to that below.

Pug-piling. The same as dovetailed piling, or pile planking.

Pulley. (Fr.) One of the five mechanical powers, consisting of a wheel or rundle, having a channel around it and turning on an axis, serving, by means of a rope which slides in its channel, for the raising of weights. See p. 391.

Pulley Mortise. The same as Chase Mortise, which see.

Pulpit. (Ital. Pulpito.) An elevated place, an enclosed stage or platform for a preacher in a church. The ancient *ambo* served the same purpose. The pulpits of the present day are generally wretched affairs, and have great affinity in form to sugar hogsheads or rum puncheons with the heads knocked out. The Catholic churches abroad almost invariably furnish fine specimens of carving and composition in their pulpits.

Pulpitum. (Lat.) See Proscenium.

Pulvinaria. (Lat.) Cushions in the ancient temples whereon the statues of the gods were sometimes laid.

Pulvinated. See Frieze.

Pump. See p. 584, 585., where the different pumps for buildings are described.

Punchion. (Fr. Poinçon.) A name common to iron instruments used in different trades for cutting, inciding, or piercing a body. In carpentry it is a piece of timber placed upright between two posts whose bearing is too great, serving, together with them, to sustain some heavy weight. The term is also applied to a piece of timber raised upright under the ridge of a building, and in which are jointed the small timbers. Also to the arbor or principal part of a machine on which it turns vertically, as that of a crane.

Purbeck Stone. A species of stone obtained from the island of Purbeck in Dorsetshire, of a very hard texture.

Purfled. (Fr. Pourfiler.) Ornamented work in stone, or other material, representing embroidery, drapery, or lace work.

Purlins. Horizontal pieces of timber lying generally on the principal rafters of a roof to lessen the bearings of the common rafters.

Puteal. The marginal stone of a well. The celebrated one of Scribonius Libo was erected by order of the senate to mark the spot where a thunderbolt had fallen near the statues of Marsyas and Janus by the Comitia.

Putlogs. See Ledgers.

Putty. A sort of paste consisting of whiting, with or without a small portion of white lead, and linseed oil, beaten together until it assumes a kind of tough consistency like dough. In this state it is used by glaziers for fixing in the squares of glass to sash windows, &c., and also by house-painters to stop up holes and cavities in woodwork before painting.

Puzzolana. A grey-coloured earth deriving its name from Puzzuoli, whence it was originally brought. It is a volcanic matter found in many other parts of Italy, and generally in the neighbourhood of volcanoes active or extinct, from which it has been thrown out in the form of ashes. It immediately hardens when mixed with one-third of its weight of lime and water, forming an admirable water cement. See Book II. Chap. II. Sect. 10.

Pycnostyle. (Gr. Πυκνος, close, and Στυλος, column.) See Colonnade.

Pyramid. (Gr. Πυρ, fire.) A solid standing on a square, triangular, or polygonal basis, and terminating at top in a point; or a body whose base is a regular rectilinear figure and whose sides are plain triangles, their several verticals meeting together in one point. It is defined by Euclid as a solid figure consisting of several triangles whose bases are all in the same plane and have one common vertex. When the base of a pyramid is but small in proportion to its height, it is called an *obelisk*. See that word. For some account of the pyramids of Egypt see Book I. Chap. II. Sect 7.

The principal properties of pyramids are as follow: — 1. All pyramids and cones standing on the same base and having the same altitude are equal. 2. A triangular pyramid is the third part of a prism, standing on the same base and of the same altitude. 3. Hence, since every multangular may be divided into triangulars, every pyramid is the third part of a prism standing on the same base and of the same altitude. 4. If a pyramid be cut by a plane parallel to its base, the sections will be similar to the base. 5. All pyramids, prisms, cylinders, &c., are in a ratio compounded of their bases and altitudes; the bases therefore being equal they are in proportion to their altitudes, and the altitudes being equal, they are in proportion to their bases. 6. Similar pyramids, prisms, cylinders, cones, &c., are in a triplicate ratio of their homologous sides. 7.

Equal pyramids, &c., reciprocate their bases and altitudes, *i. e.* the altitude of one is to that of the other, as the base of the one is to the base of the other. 8. A sphere is equal to a pyramid whose base is equal to the surface, and its height to the radius of the sphere.

Pyramid, Frustum of a. See **Frustum.**

Pyramidion. The small flat pyramid which terminates the top of an obelisk.

Pytheus. See **Architects,** list of, 8.

Q.

Quadra. (Ital.) A square border of frame round a basso-relievo, panel, &c.; the term is not strictly applicable to any circular border. The term is also applied to the bands or fillets of the Ionic base on each side of the scotia; and also to the plinth or lower member of the podium.

Quadrangle. Any figure with four angles and four sides. This term is in architecture in England applied to the inner square or rectangular court of a building, as in the college courts of Oxford, &c.

Quadrant. (Lat.) The quarter of a circle, or an arc of it containing ninety degrees within its enclosed angle.

Quadrature. (Lat.) The determination of the area of a figure in a square, or even any other rectilinear form.

Quadrels. Artificial stones perfectly square, whence their name, much used formerly by the Italian architects. They were made of a chalky or whitish and pliable earth, and dried in the shade for at least two years.

Quadrifores. (Lat.) In ancient architecture folding doors whose height was divided into two parts. When they opened in one height, they were termed *fores valvatæ* or *valvæ*.

Quadrilateral. In geometry a figure whose perimeter consists of four right lines making four angles, whence it is also called a quadrangular figure.

Quarrel, vulgarly called **Quarry.** (Fr. Carré.) A square or lozenge-shaped piece of glass used in lead casements.

Quarry. (Irish, Carrig.) A place whence stones or slates are procured. The principal stone quarries of England have been given in the body of the work, Book II. Chap. II. Sect. 1. to which place the reader is referred. The slates obtained from the different quarries of the country may be found from the information in Book II. Chap. II. Sect. 8.

Quarrying. The operation of extracting the produce of a quarry is one which requires much practical knowledge to render it beneficial to the owner of a quarry, but in respect of the particulars whereof this work does not require our notice.

Quarter Grain. See **Felt Grain.**

Quarter Pace. See **Foot Pace.**

Quarter Partition. One consisting of quarters.

Quarter Round. The same as **Ovolo** and **Echinus,** which see, being a moulding whose profile is the quadrant of a circle.

Quartering. A series of quarters, as in a partition, &c.

Quarterfoil. (Fr. Quatrefeuille.) A modern term denoting a form disposed in four segments of circles, and so called from its imagined resemblance to an expanded flower of four petals. It is only found in the windows, pannels, &c., of Gothic architecture. Mr. Gunn with charming simplicity, not unusual among the amateur writers on Gothic architecture, thinks that the form has no reference to any type in the vegetable kingdom, but that it was originally a representation of the *Greek cross* rounded towards the extremities. If the writings on the subject from the two universities of the country were all put in juxtaposition, they would perhaps afford more scope for mirth than was ever exhibited on any subject.

Quarters. Small vertical timber posts, rarely exceeding four by three inches, used instead of walls for the separation or boundary of apartments. They are placed, or ought to be, about twelve inches apart, and are usually lathed and plastered in the internal apartments, but if used for external purposes are commonly boarded.

Quartz. (Germ.) A mineral production better known by the name of rock crystal. It includes a variety of stones with which we have nothing here to do, and the only motive for mentioning it is its occurrence in the granites, wherein it is immediately recognised, from its glass-like appearance.

Quay. (Fr.) A bank formed towards the sea or on the side of a river for free passage, or for the purpose of unloading merchandise.

Queen-post. A suspending post where there are two in a trussed roof.

Quicklime. See Book II. Chap. II. Sect 10.

Quirk. A piece taken out of any regular ground-plot or floor; thus, if the ground-plan were square or oblong, and a piece were taken out of the corner, such piece is called a *quirk*

QUIRK MOULDING. One whose sharp and sudden return from its extreme projection to the re-entrant angle seems rather to partake of a straight line on the profile than of the curve. Of this class are a great number of the ancient Greek mouldings.

QUOINS. (Fr. Coin.) A term applied to any external angle, but more especially applied to the angular courses of stone raised from the naked of the wall at the corner of a building, and called rustic quoins. See RUSTIC QUOINS.

R.

RABBET. See REBATE.

RABIRIUS. See ARCHITECTS, list of, 44.

RACK. The case, enclosed by bars, over the manger in a stable, wherein the hay is placed for the horses.

RADIAL CURVES. In geometry, those of the spiral kind whose ordinates all terminate in the centre of the including circle, and appear like so many radii of such circle.

RADIUS. In geometry, the semidiameter of a circle, or a right line drawn from the centre to the circumference.

RADIUS OF CURVATURE. The radius of the osculatory circle at any point in a curve. See OSCULATORY CIRCLE.

RAFFAELLE D'URBINO. See ARCHITECTS, list of, 185.

RAFTERS. (Quasi, Roof-trees.) The inclined timbers of a roof, whose edges are in the same plane which is parallel to the covering. The rules and regulations that affect their disposition will be found in p. 544, *et seq.*

RAGS and **RAG SLATES.** See Book II. Chap. II. Sect. 8.

RAIL. (Germ. Riegel.) A term applied in various ways, but more particularly to those pieces of timber or wood lying horizontally, whether between the panels of wainscotting or of doors, or under or over the compartments of balustrades, &c.; to pieces, in framing, that lie from post to post in fences; in short, to all pieces lying in an horizontal direction which separate one compartment from another.

RAIMOND. See ARCHITECTS, list of, 93.

RAIN-WATER PIPE. One usually placed against the exterior of a house to carry off the rain-water from the roof.

RAISING PIECE. One which lies under a beam or beams and over the posts or punchions. The term is chiefly used in respect of buildings constructed of timber frame-work.

RAKING. A term applied to any member whose arrisses lie inclined to the horizon.

RAMP. (Fr.) In handrails, a concavity on the upper side formed over risers, or over a half or quarter pace, by a sudden rise of the steps above, which frequently occasions a knee above the ramp. The term is also applied to any concave form, as in coping, &c., where a higher is to be joined by a continued line to a lower body.

RAMPANT ARCH. One whose abutments or springings are not on the same level.

RANGE or **RANGING.** (Fr.) A term applied to the edges of a number of bodies when standing in a given plane. Thus, if the edges of the ribs of a groin were placed in a cylindric surface, they would be said to *range*. It is also used in respect of a work that runs straight without breaking into angles.

RANULPH. See ARCHITECTS, list of, 91.

RARI. See ARCHITECTS, list of, 140.

RATE. An expression used in the Building Act (see p. 819.) to denote the particular class to which a building belongs, in order to determine the thickness of its walls and mode of building.

RAY, PRINCIPAL. In perspective, the perpendicular distance between the eye and the perspective plane.

REBATE. (Fr. Rebattre.) A groove or channel cut on a piece of wood, longitudinally, to receive the edge of a body, or the ends of a number of bodies that are to be secured to it. The depth of the channel is equal to the thickness of the body; so that when the end of the latter is let into the rebate, it is in the same face with the outside of the piece.

REBATE PLANE. One used for sinking rebates.

RECESS. (Lat. Recedo.) A cavity left in a wall, sometimes for use, as to receive a sideboard, bed, &c., or to add to the quantity of floor room, and sometimes for ornament, as when formed into a niche, &c.

RECTANGLE. In geometry, a figure whose angles are all right angles. Solids are called rectangular with respect to their position, as a cone, cylinder, &c., when perpendicular to the plane of the horizon. A parabola was anciently called a rectangular section of a cone.

Rectification. In geometry, the finding of a right line that shall be equal to a given curve, or simply finding the length of a curve.

Rectilinear. A figure whose boundaries are right lines.

Rede. See Architects, list of, 143.

Reduct. A quirk or small piece taken out of a larger to make it more uniform and regular.

Reduction of a figure, design, or draught, is the copying it on a smaller scale than the original, preserving the same form and proportions. For this purpose a pair of proportional compasses are generally used, by which the labour is much lessened.

Refectory. (Lat.) A room for taking refreshments. See Abbey.

Reflex. The light reflected from a surface in light to one in shade.

Reglet. (Fr.) A flat narrow moulding, used chiefly to separate the parts or members of compartments or panels from each other, or to form knots, frets, and other ornaments.

Regrating. In masonry, the process of removing the outer surface of an old hewn stone, so as to give it a fresh appearance.

Regula. (Lat.) A band below the tænia in the Doric architrave.

Regular. An epithet to a figure when it is equilateral and equiangular. A body is said to be regular when it is bounded by regular and equal planes, and has all its solid angles equal.

Regular Architecture. That which has its parts symmetrical or disposed in counterparts.

Regular Curves. The perimeters of conic sections, which are always curved after the same geometrical manner.

Reins of a Vault. The sides or walls that sustain the arch.

Rejointing. The filling up the joints of stones in old buildings when the mortar has been dislodged by age and the action of the weather.

Relation. The direct conformity to each other, and to the whole, of the parts of a building.

Remigius. See Architects, list of, 82.

Rendering. The act of laying the first coat of plaster on brickwork.

Replum. (Lat.) In ancient architecture, the panel of the impages of a framed door.

Reredos. (Fr. Arriéredos.) A screen or division wall placed behind an altar, rood-loft, &c., in old churches.

Reservoir. (Fr.) An artificial pond, basin, or cistern for the collection and supply of water.

Resistance. That power which, acting in opposition to another, tends to destroy or diminish its effect. There are several sorts of resistance, arising from the various natures and properties of the resisting bodies, as the resistance of solids, fluids, air, &c.

The resistance of solid bodies is the force with which their quiescent parts retain their aggregation. Of it there are two kinds: first, where the resisting and the resisted parts are only contiguous and do not cohere, or, in other words, where they consist of separate bodies or masses. This is by Leibnitz called the *resistance of the surface*, now however called *friction*. Second, where the resisting and resisted parts are not only contiguous, but cohere, that is, are parts of the same continued body or mass. To these may be added the resistance that takes place between surfaces or solids when completely in contact, though not forming the same body, or the resistance they offer to separation. To form a notion of the resistance of the fibres of solid bodies, suppose a cylindrical body suspended vertically by one of its ends. Here the weight of the parts makes them tend downwards and endeavours to separate the body where it is weakest. The parts, however, resist this separation by the force with which they cohere. In this case, then, we see two opposite powers, viz. the weight of the cylinder, which has a tendency to break it, and the force of cohesion to resist fracture. If the base of the cylinder be increased, the length remaining the same, it is manifest that the resistance will increase as the base; but the weight will also increase in the same ratio. Hence, all cylinders of the same matter and length, when vertically suspended, have an equal resistance, whatever their bases. When the length of the cylinder is increased, the base and the resistance remaining the same, the additional weight weakens it, and it will have a greater tendency to break.

We thus learn what length a cylinder may be so as to break with its own weight, by finding what weight is just sufficient to break another cylinder of the same base and matter; for the required length must be such that its weight may be equal to that of the first, with the additional weight employed to produce the separation.

If the cylinder be fixed horizontally into a wall, and the rest thence suspended, the weight and resistance will act under different conditions, for if it broke by the action of its weight, the fracture would occur at the end fixed into the wall. In the fracture of the cylinder two forces have acted, and one has overcome the other; that is, the weight of the mass of the cylinder has overcome the resistance arising from the largeness of the base; and as the centres of gravity are points in which all the forces arising from the weights of the several parts of the same bodies are supposed to be collected, we may conceive the weight of the whole cylinder applied in the centre of gravity of its mass, that is, in a point in the middle of the axis; and the resistance of the cylinder applied in the centre of gravity of its base, it being the base which resists the fracture. If the cylinder breaks with its own weight all the motion is on an immoveable extremity of the diameter of the base, which extremity is the fixed point of a lever, whose arms are the radius of the base and half the axis; hence, the two opposite forces do not only act of themselves and by their absolute, but also by the relative force derived from their distance with regard to the fixed point of the lever.

The weight required to break a body placed horizontally being always less than that required to break it when placed vertically, and being greater or less according to the ratio of the two arms of the lever, the theory is reducible to the finding what part of the absolute weight the relative weight must be, supposing the figure of the body known, which is necessary for finding the centre of gravity. But wherever the centre of gravity falls, the two arms of the lever are estimated accordingly. If the base by which the body is fixed in the wall be not circular, but, for an example, parabolical, and the vertex of the parabola be at top, the motion of the fracture will not be on an immoveable point, but on a whole immoveable line, which may be termed the axis of equilibrium, and it is with regard thereto that the distances of the centres of gravity are to be determined.

A body horizontally suspended, being such that the smallest addition of weight would break it, there is an equilibrium existing between its positive and relative weight; those two opposite powers are consequently to each other reciprocally as the arms of the lever to which they are applied. So, *e converso*, the resistance of a body is always equal to the greatest weight it will sustain, without breaking, in a vertical situation, that is, equal to its absolute weight. If we, therefore, substitute actual weight for the resistance, it follows that the absolute weight of a body suspended horizontally is to its relative weight, as the distance of the centre of gravity from the axis of equilibrium is to the distance of the centre of gravity of its base from the same axis. From this fundamental proposition many consequences are deducible. Thus, if the distance of the centre of gravity of the base from the axis of equilibrium be half the distance of the centre of gravity of the body, the relative weight will only be half the absolute weight.

M. Mariotte having observed that all bodies bend before breaking, considers the fibres as so many little bent springs, never exerting their whole force till stretched to a certain point, and never breaking till entirely unbent. Hence those nearest the axis of equilibrium, which is an immoveable line, are less stretched than the more distant ones, and consequently employ a less part of their force.

The following is a synopsis of the most important results that have been drawn by different writers on the subject, both practical and theoretical: —

1. The resistance of a beam or bar to a fracture by a force acting laterally is as the solid made by a section of the beam in the place where the force is applied, into the distance of its centre of gravity from the point or line where the breach will end.

2. In square beams the lateral strengths are as the cubes of their breadths and depths.

3. In cylindric beams, the resistances of strengths are as the cubes of the diameters.

4. In rectangular beams the lateral strengths are conjointly as the breadths and squares of the depths.

5. The lateral resistances of any beams whose sections are similar figures and alike placed are as the cubes of the like dimensions of those figures.

6. The lateral strength of a beam, with its narrower face upwards, is to its strength with the broader face upwards, as the breadth of the broader face to the breadth of the narrower.

7. The lateral strengths of prismatic beams, of the same materials, are as the areas of the sections and the distance of their centre of gravity directly, and as their lengths and weights reciprocally.

8. When the beam is fixed at both ends, the same property has place, except that in this case we must consider the beam as only half the length of the former.

9. Cylinders and square prisms have their lateral strengths proportional to the cubes of their diameters or depths directly, and their lengths and weights inversely.

10. Similar prisms and cylinders have their strength inversely proportional to their linear dimensions.

The relative resistance of wood and other bodies is shown in the following table: —

	Proportional Resistance.
Box, yew, plum tree, oak - - - -	11
Elm, ash - - - - - -	8½
Walnut, thorn - - - - -	7½
Red fir, holly, elder, plane, crab-tree, apple-tree -	7
Beech, cherry-tree, hazel - - - -	6⅔

	Proportional Resistance.
Alder, asp, birch, white fir, willow	6
Iron	107
Brass	50
Bone	22
Lead	6½
Fine freestone	1

The following table shows the cohesive force of a square inch of different substances from the experiments of Professor Robinson: —

	lbs.
Gold when cast	20·000
Silver	40·000
Cast iron	40·000 to 60·000
Wrought iron	60·000 to 90·000
Soft steel	12·000
Razor steel	15·000
Oak and beech in the direction of their fibres from	8·000 to 17·000
Willow	12·000
Fir	8·000
Cedar	5·000
Ivory	16·000
Bone	5·000
Rope	20·000

Resolution of Forces. See p. 381.

Ressault. (Fr.) The recess or projection of a member from or before another, so as to be out of the line or range with it.

Retaining Walls. Such as are built to retain a bank of earth from sliding down.

Reticulated. Like the meshes of a net. The *reticulatum opus* of the ancients is described under the article Masonry, which see.

Return. The continuation of a moulding, projection, &c., in an opposite direction. A side or part which falls away from the front of a straight work.

Return Bead. See Bead and Double Quirk.

Reveals. (Lat. Revello.) The vertical sides of an aperture between the front of the wall and the window or door frame.

Revolution. In geometry, the motion of a point or line about a centre. Thus a right-angled triangle, revolving round one of its legs as an axis, generates a cone in its revolution.

Rhomboid. (Gr.) A quadrilateral figure whose opposite sides and angles are equal.

Rhombus. (Gr.) A quadrilateral figure, whose sides are all equal, and whose opposite angles are respectively equal, two being obtuse and two acute.

Rib. (Sax.) An arch-formed piece of timber for supporting the lath and plaster work of a vault.

Ribbing. An assemblage of ribs for a vault or coved ceiling.

Ridge. (Sax.) The highest part of a roof. The term is more particularly applied to the piece of timber against which the upper end of the rafters pitch.

Ridge Tile. A convex tile made for covering the ridge of a roof.

Riga Timber. See p. 484.

Right Angle. One containing ninety degrees.

Right Circle. A circle drawn at right angles with the plane of projection.

Right Line. A line perfectly straight.

Rilievo (It.) or Relief. The projecture from its ground of any architectural ornament. Among sculptors there are three degrees of rilievo; namely, *alto rilievo*, when the figure stands quite out from its ground; *mezzo rilievo*, when one half of the figure projects; and *basso rilievo*, when the figures are raised from the ground in a small degree.

Ripley. See Architects, list of, 283.

Rod. A measure of length equal to 16½ feet. A square rod is the usual measure of brick-work, and is equal to 272¼ square feet.

Rod Stone or Oolite. A kind of limestone, found under chalk in various parts of England. See Book II. Chap. II. Sect. 4.

Roger, Archbishop of York. See Architects, list of, 97.

Rolls. Pieces of wood prepared for the plumber to turn over the lead where the sheets join, so as to protect the flat roof or edge from the admission of water. The term also signifies in Gothic architecture mouldings representing bent cylinders.

Rolls or Rollers. Among workmen are plain cylinders of wood, seven or eight inches diameter and three or four feet long, used for the purpose of moving large stones, beams, and other heavy weights. They are placed successively under the fore part of the masses to be removed, and at the same time are pushed forward by levers applied behind. When blocks of marble, or other very heavy weights, are to be moved, they use what are called *endless rolls*. These, to give them the greater force and prevent their bursting, are made of wood joined together by cross-quarters, double the length and thickness of the common rollers, and girt with iron hoops at each end. At a foot from the ends are two mortises pierced through and through, into which are put the ends of long levers, which the workmen draw by ropes fastened to the ends, still changing the mortise as the roll has made a quarter of a turn.

Roman Architecture. See Book I. Chap. II. Sect. 13.

Roman Order. The same as Composite Order, which see.

Romualdus. See Architects, list of, 71.

Rood. (Sax. Robe.) A cross, crucifix, or figure of Christ on the cross placed in a church. The *holy rood* was one, generally as large as life, elevated at the junction of the nave and choir, and facing to the western entrance of the church. The *rood loft* was the gallery in which the rood and its appendages were placed. This loft, or gallery, was commonly placed over the chancel screen in parish churches. In Protestant churches the organ now occupies the original place of the rood loft. The *rood tower* or *steeple* was that which stood over the intersection of the nave with the transepts.

Roof. (Sax. Roꝼ, Hꞃoꝼ.) The exterior covering of a building, for whose principles of construction and various sorts the reader is referred to p. 544, *et seq.*

Roofing. The assemblage of timbers, and covering of a roof whose pitch in this climate, for different coverings, is shown in the following table: —

Species of Covering.	Inclination to the Horizon.	Height of Roof in Part of the Span.
Copper or lead	3° 50″	one-forty-eighth.
Large slates	22 0	one-fifth.
Common slates	26 33	one-quarter.
Stone slates	29 41	two-sevenths.
Plain tiles	29 41	two-sevenths.
Pan tiles	24 0	two-ninths.
Thatch	45 0	one-half.

Room. (Sax. Rum.) An interior space or division of a house, separated from the remainder of it by walls or partitions, and entered by a doorway.

Rooms, Proportions of. See Book III. Chap. I. Sect. 25.

Rose or Rosette. An ornament of frequent use in architectural decorations. The centre of the face of the abacus in the Corinthian capital is decorated with what is called a rose.

Rose Window. A circular window with compartments of mullions and tracery branching from a centre, sometimes called a *catharine wheel* or *marigold window*.

Rostrum. (Lat.) Literally, the beak of a bird; also the beak or fore-part of a ship; the elevated platform in the Forum of ancient Rome, whence the orators addressed the people, so called from its basement being decorated with the prows of ships. The term is now used generally to signify a platform or elevated spot from which a speaker addresses his audience.

Rot, dry. An extremely destructive disease incident to timber. See p. 490.

Rotunda or Rotondo. (Ital.) A building circular on the interior and exterior, such as the Pantheon at Rome. See Circular Buildings.

Rough-cast. A species of plastering used on external walls, consisting of a mixture of lime, small shells or pebbles, occasionally fragments of glass and similar materials. This is usually applied to cottages.

Rudenture. (Lat. Rudis, a rope.) The same as Cabling, which see.

Ruderation. (Lat. Ruderatio.) A method of laying pavements, mentioned by Vitruvius, and according to some, of building walls with rough pebbles and mortar. The mortar called *statumen* by Vitruvius was made of lime and sand.

Ruiz. See Architects, list of, 226.

Rule. An instrument for measuring short lengths. Of rules there are various sorts, each adapted to the class of artificers for whose use they are made. Thus, there are stone-cutters' rules, masons' rules, carpenters' rules, sliding and parallel rules, &c. The sliding rule is, however, of more general use, as it solves a number of questions from the change of the position of the slider by inspection, and therefore of much importance to the less educated artisan.

Rural Architecture. See Book III. Chap. III. Sections 22, 23, and 24.

Russian Architecture. Book I. Chap. II. Sect. 20.

Rustic Order. A species of building wherein the faces of the stones are hatched or picked with the point of a hammer.

Rustic Quoins or Coins. The *lapides minantes* of Vitruvius, the stones placed on the external angles of a building projecting beyond the naked of the wall. The edges are bevelled, or the margins recessed in a plane parallel to the face or plane of the wall.

Rustic Work. A mode of building masonry wherein the faces of the stones are left rough, the sides only being wrought smooth where the union of the stones takes place. It was a method much practised at an early period, and re-introduced by Brunelleschi at the revival of the arts. The most common sorts of rustic work are the *frosted*, which has the margins of the stones reduced to a plane parallel to that of the wall, the intermediate parts having an irregular surface; *vermiculated* rustic work, wherein the intermediate parts present the appearance of having been worm-eaten; *chamfered* rustic work, in which the face of the stones being smoothed and made parallel to the surface of the wall, and the angles bevelled to an angle of one hundred and thirty-five degrees, with the face of the stone, where they are set in the wall, the bevel of the two adjacent stones forms an internal right angle.

S.

Sablière. (Fr.) An obsolete word, signifying a piece of timber as long as a beam, but not so thick.

Sacchetti. See Architects, list of, 286.

Sacellum. (Lat.) In ancient Roman architecture, a small inclosed space without a roof. Small sacella, too, were used among the Egyptians, attached frequently to the larger temples. In old church architecture, the term signifies a monumental chapel within a church, also a small chapel in a village.

Sacome. (Ital.) The exact profile of a member or moulding, applied by the French to the mouldings themselves.

Sacrarium. (Lat.) A small sacred apartment in a Roman house, devoted to a particular deity; also the *cella*, *penetrale* or *adytum* of a temple.

Sacristy. See Diaconicum.

Saddle-backed Coping. See Coping.

Sag or Sagging. The bending of a body by its own weight when resting inclined or horizontally on its ends.

Sagitta. (Lat. an arrow.) A name sometimes applied to the keystone of an arch. In geometry, it is often employed to signify the abscissa of a curve; and in trigonometry it is the versed sine of an arc, which, as it were, stands like a dart upon the chord.

Sail over. See Projecture.

Saliant. (Fr.) A term used in respect of a projection of any part or member.

Sally. A projecture. The end of a piece of timber cut with an interior angle formed by two planes across the fibres. Thus the feet of common rafters, and the inclined pieces which support the flying steps of a wooden stair, are frequently cut; as are, likewise, the lower ends of all inclined timbers which rest upon plates or beams.

Salon or Saloon. (Fr.) A lofty and spacious apartment, frequently vaulted at top, and usually comprehending the height of two floors with two tiers of windows. Its place is commonly in the middle of a building, or at the head of a gallery, &c. In palaces it is the state room.

San Gallo Antonio. See Architects, list of, 199.

San Gallo di Giul. See Architects, list of, 178.

San Lucano. See Architects, list of, 183.

San Micheli. See Architects, list of, 213.

Sand. See Book II. Chap. II. Sect. 10.

Sandstone. In mineralogy, a stone principally composed of grains, or particles of sand, either united with other mineral substances or adhering without any visible cement. The grains or particles of sandstone are generally quartz, sometimes intermixed with feldspar or particles of slate. When lime is the cementing matter the stone is called calcareous sandstone. The cementing matter is not unfrequently oxide of iron intermixed with alumine. The particles of sand in these stones are of various sizes, some being so small as to be scarcely visible. See Book II. Chap. II. Sect. 1.

Sap. The juice or pith of trees that rises from the earth and ascends into the arms, branches, and leaves, to feed and nourish them. Also that part of the stem or wood of the body of a tree that is soft, white, &c. The term is used also as a verb, to denote the undermining a wall by digging a trench under it.

Sapheta. The same as Soffite or Sofite, which see.

Saracenic Architecture. See Book I. Chap. II. Sect 10.

Sarcophagus. (Σαρξ flesh, and Φαγω, to eat.) A tomb or coffin made of one stone. From Pliny it appears to have been originally applied as the name of a stone found in the Troad, which, from its powerful caustic qualities, was selected for the construction of tombs. From its frequent application to this purpose the name became at length used for the tomb itself. Sarcophagi were made of stone, marble, alabaster, porphyry, &c. The Greeks sometimes made them of hard wood, as oak, cedar, or cypress, which resisted moisture; sometimes of terra cotta, and even of metal. The form was usually a long square, the angle being rounded. The lid varied both in shape and ornament. Those of the primitive Christians often enclosed several corpses, and were ornamented with several sets of bassi rilievi. Those of higher antiquity were frequently sculptured with great taste and beauty of design, the figures being those of the deceased, or parties connected with them, allegorical or mythological. The Egyptian sarcophagi are sculptured with hieroglyphics. Those of the Greeks and Romans sometimes represent Sleep and Death with their legs crossed, one hand supporting the head and the other holding an inverted torch; sometimes Mercury is represented conducting the Souls and Charon ferrying them over in his bark. Occasionally we find on them groups of bacchanals and bacchic scenes.

Sash. (Fr. Chasis, a frame.) A frame for holding the glass of windows, and so formed as to be raised and depressed by means of pulleys. Sashes are single or double hung, or hung with hinges. See p. 572.

Sash Frame. The frame in which the sashes are fitted for the convenience of sliding up and down, or, when hung with hinges, to receive them after the manner of hanging a door.

Saurus. See Architects, list of, 34.

Saw. (Dutch, Sawe.) A tool made of a thin plate of steel, formed on the edge into regular teeth for cutting wood, stone, &c. Saws are of various kinds. See p. 565.

Saw-pit. A pit excavated for sawing timber. The sawing is performed by two persons called *sawyers*, one standing above and the other below. Much of the labour, however, is saved by the use of a saw-mill, or machine moving a circular saw, which by its revolutions and keeping the timber close up, performs the work quicker and better than can be done by the labour just described.

Saxon Architecture. See Book I. Chap. III. Sects. 1 and 2.

Saxulphus. See Architects, list of, 66.

Scabellum. (Lat.) A species of pedestal anciently used to support busts or statues. It was high in proportion to its breadth, ending in a kind of sheath, or in the manner of a baluster.

Scaffold. (Fr. Echaufaud.) An assemblage of planks or boards sustained by pieces of wood made fast to vertical poles, and at the other end often resting on the walls, by means whereof the workmen carry up a building, or plasterers complete their work in the interior of houses. On the Continent, scaffolds for public building are much more solidly constructed than in this country.

Scagliola. (Ital.) A species of plaster or stucco invented at Carpi, in the state of Modena, by Guido Sassi, between 1600 and 1649. It is sometimes called *mischia*, from the mixture of colours introduced in it. It was not, however, till the middle of the eighteenth century that the art of making scagliola was brought to perfection. The following is the method of making columns and pilasters:—A wooden cradle, composed of thin strips of deal or other wood is made to represent the column designed, but about 2¼ inches less in diameter than the shaft is intended to be when finished. This cradle is lathed round, as for common plastering, and then covered with a pricking-up coat of lime and hair. When this is quite dry, the scagliola artist commences his operations, and, by imitating the rarest and most precious marbles, produces a work which cannot be, except by fracture or sound, discovered to be counterfeit. The purest gypsum which can be obtained is broken into small pieces, and calcined. As soon as the largest fragments lose their brilliancy, the fire is withdrawn; the calcined powder is passed through a very fine sieve, and mixed up with a solution of Flanders glue, isinglass, &c. In this solution the colours are diffused that are required to be imitated in the marble; but if the work is to be of various colours, each colour is separately prepared, and they are afterwards mingled and combined nearly in the same manner that a painter mixes the primitive colours on his palette to compose his different tints. When the powdered gypsum is prepared and mingled for the work, it is laid on the shaft of the column or other surface over the pricked-up coat of lime and hair, and it is then *floated* with proper moulds of wood, the artist during the *floating* using the colours necessary for the imitation, by which means they become mingled and incorporated with the surface. The process of polishing follows; and this is done by rubbing the surface with pumice-stone in one of his hands, while with the other he cleans it with a wet stone. It is then polished with tripoli and charcoal and fine and soft linen; and after going over it with a piece of felt dipped in a mixture of oil and tripoli, he finishes with application of pure oil.

Scale. (Sax.) A line divided into a certain number of equal parts, usually on wood, ivory, or metal, for laying down heights and distances in mathematical and architectural drawing. There are various sorts of scales; as, the *plane scale*, *Gunter's scale*, the *diagonal scale*, &c.; but the most generally useful scale is that wherein the objects are drawn some aliquot part of their real size, as a tenth, twelfth, twentieth, twenty-fourth, &c.

Scalene Triangle. (Σκαληνος, oblique.) In geometry, one whose sides are all unequal.

Scamilli impares. A term used by Vitruvius, which has puzzled all the commentators.

It probably signifies certain blocks which serve to raise some of the members of a building, which, from being placed below the level, or below the projection of certain ornaments, might be lost to the eye.

Scamillus. A small plinth below the bases of the Ionic and Corinthian columns.

Scammozzi. See Architects, list of, 247.

Scandulæ. (Lat.) In early buildings of the Romans, shingles or flat pieces of wood used for covering instead of tiles. According to Cornelius Nepos, this was the only covering used in Rome till the war with Pyrrhus in the 470th year of the city.

Scantling. (Fr.) The dimensions of a piece of timber in breadth and thickness. It is also a term used to denote a piece of timber, as of quartering in a partition, when under five inches square, or the rafter, purlin, or pole plate of a roof. In masonry, scantling is the length, breadth, and thickness of a stone.

Scape or **Scapus.** (Gr.) The shaft of a column; also the little hollow, above or below, which connects the shaft with the base, or with the fillet under the astragal.

Scapling. A method of tooling the face of a stone.

Scarfing. The joining of two pieces of timber by bolting or nailing transversely together, so that the two appear but one. See p. 538.

Scene. (Gr. Σκηνη.) Strictly an alley or rural portico for shade or shelter, wherein, according to Cassiodorus, theatrical pieces were first represented. When first applied to a theatre, it signified the wall forming the back of the stage, but afterwards came to mean the whole stage, and is now restricted to the representation of the place in which the drama represents the action. According to Vitruvius, the Greek scene was occupied in the middle by a great door, called the royal door, because decorated as the gate of a palace. At the sides were smaller doors, called *hospitalia*, because representing the entrances to habitations destined for strangers, which the Greeks commonly placed on the two sides of their houses.

Scenography. (Gr.) The method of representing solids in perspective.

Scheme or **Skene Arch.** One which is a segment of a circle.

Schene. (Gr.) The representation of any design or geometrical figure by lines so as to make it comprehensible.

Scholium. In mathematics, a remark after the demonstration of a proposition, showing how it may be done some other way, or giving some advice or precaution to prevent mistakes, or adding some particular use or application thereof.

Sciagraphy or **Sciography.** (Gr. Σκια, a shadow, and Γραφω, I describe.) The doctrine of projecting shadows as they fall in nature. See Book II. Chap. IV. Sect. 3.

Scopas. See Architects, list of, 16.

Scotia. (Gr. Σκοτια, darkness.) The hollow moulding in the base of a column between the fillets of the tori. It receives the name from being so much in shadow. The scotia was, from its resemblance to a pulley, called also τροχιλον. It is most frequently formed by the junction of circular areas of different radii, but it ought rather to be profiled as a portion of an ellipsis.

Scratch Work. (It. Sgraffiata.) A species of fresco with a black ground on which a white plaster is laid, which being scratched off with an iron bodkin, the black appears through the holes, and serves for shadows.

Screen. (Lat. Excerno.) An instrument used in making mortar, consisting of three wooden ledges joined to a rectangular frame at the bottom, the upper part of which frame is filled with wirework for sifting the sand or lime. This term is used in ecclesiastical architecture to denote a partition of wood, stone, or metal, usually so placed in a church as to shut out an aisle from the choir, a private chapel from a transept, the nave from the choir, the high altar from the east end of the building, or an altar tomb from one of the public passages or large areas of the church. In the form and ornamental detail of screens, the ancient artists appear to have almost exhausted fancy, ingenuity, and taste.

Screw. (Dutch, Scroeve.) One of the six mechanical powers, chiefly used in pressing or squeezing bodies close, though sometimes also in raising weights. See Book II. Chap. I. Sect. 8.

Scribing. Fitting the edge of a board to a surface not accurately plane, as the skirting of a room to a floor. In joinery, it is the fitting one piece to another, so that the fibres of them may be perpendicular to each other, the two edges being cut to an angle to join.

Scroll. A convolved or spiral ornament variously introduced. Also the volutes of the Ionic and Corinthian capital. See *fig.* 1046.

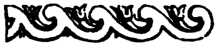

Fig. 1046.

Scullery. The apartment for washing up the dishes and utensils wherein the scullion works.

Sculpture. (Lat. Sculpo, to carve.) The art of imitating forms by chiselling and working away solid substances. It is also used to denote the carved work itself. Properly, the word includes works in clay, wax, wood, metal, and stone; but it is generally restricted to those of the last material, the terms *modelling*, *casting*, and *carving* being applied to the others.

Sealing. The fixing a piece of wood or iron on a wall with plaster, mortar, cement, lead, or other binding, for staples, hinges, joints, &c.

Seasoning Timber. See p. 491.

Secant. (Lat.) A line that cuts another. In trigonometry, the secant is a line drawn to the centre from some point in the tangent, which consequently cuts the circle.

Secos. See Adytum.

Section of a Building. A geometrical representation of it as divided or separated into two parts by a vertical plane, to show and explain the construction of the interior. The section not only includes the parts that are separated, but also the elevation of the receding parts, and ought to be so taken as to show the greatest number of parts, and those of the most difficult construction. Of every building at least two sections should be made at right angles to one another, and parallel to the sides. A section of the flues should also be made, in order to avoid placing timbers near them.

Section of a Solid. The plane of separation dividing one part from the other. It is understood to be always a plane surface.

Sector. An instrument for measuring or laying off angles, and dividing lines and circles into equal parts.

Sector of a Circle. The space comprehended between two radii and the arc terminated by them.

Segment. (Lat.) A part cut off from anything. The area contained by the arc of a circle and a chord. In the segment of a circle the chord of the arc is called the base of the segment, and the height of the arc the height of the segment.

Segment of a Sphere. A portion cut off by a plane in any part except the centre, so that the base of such segment must be always a circle, and its surface a part of the sphere.

Sell. See Cill and Aperture.

Semicircle. The half of a circle contained by the diameter and circumference.

Semicircular Arches. Those whose arcs are semicircular.

Sennamar. See Architects, list of, 55.

Sepulchre. (Lat. Sepelire, to bury.) A grave, tomb, or place of interment. The *cenotaph* was an empty sepulchre raised in honour of a person who had had no burial.

Seraglio. The palace of an eastern prince, but more particularly that in which the females are lodged.

Serlio. See Architects, list of, 238.

Serpentine. See Porphyry.

Servandoni. See Architects, list of, 288.

Sesspool. See Cesspool.

Sett. In piling, a piece placed temporarily on the head of a pile which cannot be reached by the monkey or weight from some intervening matter.

Setting. The hardening of cement. The term is also used in masonry for fixing stones in walls or vaults, in which the greatest care should be taken that the stones rest firmly on their beds, and that their faces be ranged in the proper surface of the work.

Setting-out Rod. One used by joiners for setting-out frames, as of windows, doors, &c.

Settlements. Those parts in which failures by sinking in a building have occurred.

Sett-off. The projecting part between the upper and lower portion of a wall where it diminishes in thickness.

Severus. See Architects, list of, 43.

Severy. A compartment or division of scaffolding. It is also a separate portion or division of a building corresponding with the modern term compartment, being as it were severed or divided.

Sewer. A drain or conduit for carrying off soil or water from any place. See Book II. Chap. III. Sect. I.

Sexagesimal. The division of a line, first into sixty parts, then each of these again into sixty, and so on, as long as division can be made. It is principally used in dividing the circumference of a circle.

Shadows and Shadowing. In drawing, the art of correctly casting the shades of objects and representing their degrees of shade. See Book II. Chap. IV. Sect. 3.

Shaft. (Sax. Sceaft.) The cylindrical part, or rather body, of a column, between the base and the capital. It is, properly, the frustum of a conoid, and is also called the *fust*, *trunk*, or body of the column.

Shaft of a Chimney. See Chimney.

Shaft of a King Post. The part between the *joggles*.

Shake. A fissure or rent in timber by its being dried too suddenly, or exposed to too great heat. Any timber when naturally full of slits or clefts is said to be *shaky*.

Shanks. (Sax.) The space between two channels of the Doric triglyph, sometimes called the legs of the triglyph. The ancients called the *shank femur*.

Sheet Lead. See Book II. Chap. III. Sect. 7.

Shelf. (Sax.) A board fixed against a wall by its edge, the upper side being horizontal, for receiving whatever may be placed upon it. A shelf is usually supported by brackets, or by pieces at the end, called *standards*.

Shingles. (Germ. Schindel.) Small oaken boards used like slates for covering a building, from eight to twelve inches long, and about four inches broad, thicker on one edge than the other. The process of making a roof of this kind is called *shingling*.

Shoe. The inclined piece at the bottom of a water trunk or lead pipe for turning the course of the water, and discharging it from the wall of a building.

Shore or **Shoar.** (Sax.) A prop or oblique timber acting as a brace on the side of a building, the upper end resting against that part of the wall upon which the floor is supported, and both ends received by plates or beams. A *dead shore* is an upright piece built up in a wall that has been cut or broken through for the purpose of making some alterations in the building.

Shooting. Planing the edge of a board straight, and out of winding.

Shooting Boards. Two boards joined together, with their sides lapped upon each other, so as to form a rebate for making short joints.

Shoulder of a Tenon. The plane transverse to the length of a piece of timber from which the tenon projects. It should be at right angles to the length, though it does not always lie in the plane as here defined, but sometimes in different planes.

Shread Head The same as Jerkin Head, which see.

Shreddings or **Furrings.** In old buildings, short slight pieces of timber fixed as bearers below the roof, forming a straight line with the upper side of the rafters.

Shrine. (Sax. Scrin.) A desk or cabinet; a case or box, particularly one in which sacred things are deposited: hence applied to a reliquary and to the tomb of a canonised person. The altar is sometimes called a shrine, and in this case its form and condition, and the annexation of a statue to it, was of importance, because such tombs had greater privileges than plainer monuments.

Shrinking. The contraction of a piece of timber in its breadth by seasoning, hot water, &c. It is proportional to its breadth, the length not changing. Hence in unseasoned timber mitred together, such as the architraves of doors and windows, the mitres are always close on the outside and open to the door, forming a wedge-like hollow on each side of the frame. It is to avoid the effects of shrinking that narrow boards called *battens* are used in floors.

Shute. See Architects, list of, 243.

Shutters. The boards which shut up the aperture of a window. See Boxings of a Window.

Side Posts. Truss posts placed in pairs, disposed at the same distance from the middle of the truss. Their use is not only to support the principal rafters, &c., but to suspend the tie beam below. In extended roofs two or three pair of side posts are used.

Side Timbers or **Side Wavers.** The same as purlins, the first term being used in Somersetshire and the last in Lincolnshire.

Sienite. See Syenite.

Sill. See Cill and Aperture.

Siloe. See Architects, list of, 211.

Silt. The muddy deposit of standing water.

Sima. See Cyma.

Similar Figures. Those whose several angles are respectively equal, and the sides about the equal angles proportional.

Simonetti. See Architects, list of, 296.

Sine. A right line drawn from one end of an arch perpendicular upon the diameter, or it is half the chord of twice the arch. The sine of the complement of an arch is the sine of what the arch wants of ninety degrees. The *versed sine* is that part of the diameter comprehended between the arc and the sine.

Single Frame and **Naked Floor.** One with only one tier of joists.

Single Hung. An arrangement in a pair of window sashes, in which one only is movable.

Single Joists Floor. One without binding joists.

Single Measure. A term applied to a door that is square on both sides. *Double measure* is when the door is moulded on both sides. When doors are moulded on one side and are square on the other, they are accounted measure and half.

Sissiverne. See Architects, list of, 101.

Site. (Lat. Situs.) The situation of a building; the plot of ground on which it stands.

Skew Back. In a straight or curved arch, that part of it which recedes on the springing from the vertical line of the opening.

Skirting or **Skirting Board.** The narrow board placed round the margin of a floor, which, where there is a dado, forms a plinth for its base; otherwise, it is a plinth for the room itself. Skirting is either scribed close to the floor or let into it by a groove; in the former case a fillet is put at the back of the skirting to keep it firm.

Skirts. Several superficies in a plane, which would cover a body when turned up or down without overlapping.

Skreen. See Screen.

Skylight. A frame consisting of one or more inclined planes of glass, placed in a roof to light passages or rooms below.

Slab. An outside plank or board sawed from the sides of a timber tree, and frequently of very unequal thickness. The word is also used to express a thin piece of marble, consisting of right angles and plane surfaces. See Chimney.

Slate. See Book II. Chap. II. Sect. 8.

Slaters' Work. See Book III. Chap. II. Sect. 6.

Sleepers. Horizontal timbers disposed in a building next to the ground transversely under walls, ground joists, or the boarding of a floor. When used on piles they are laid upon them, and planked over to support the superincumbent walls. Underground joists either lie upon the solid earth, or are supported at various parts by prop stones. When in the former position, having no rows of timber below, these ground joists are themselves called sleepers. Old writers on practical architecture call those rafters lying in the valley of a roof, sleepers; but in this sense the word is now obsolete.

Sliding Rule. One constructed with logarithmic lines, so that by means of another scale sliding on it, various arithmetical operations are performed merely by inspection.

Slit Deal. See Board.

Sluice. A stop against water for the drainage or supply with water of a place. It is hung with hinges from the top edge when used merely as a stop against the water of a river; but when made for supply as well, it moves vertically in the groove of its frame by means of a winch, and is then called a penstock.

Smithery and **Ironmongery.** See Book II. Chap. III. Sect. 10.

Smoothing Plane. See p. 364.

Snacket. A provincial term for the hasp of a casement.

Snipe's Bill Plane. One with a sharp arris for getting out the quirks of mouldings.

Soane. See Architects, list of, 316.

Socket Chisel. A strong tool used by carpenters for mortising, and worked with a mallet.

Socle or **Zocle.** A square member of less height than its horizontal dimension, serving to raise pedestals or to support vases or other ornaments. The socle is sometimes continued round a building, and is then called a *continued socle*. It has neither base nor cornice.

Soffita, Soffit, or **Sofite.** (Ital.) A ceiling; the lower surface of a vault or arch. A term denoting the under horizontal face of the architrave between columns; the under surface of the corona of a cornice.

Soils. A provincial term, chiefly, however, used in the north, signifying the principal rafters of a roof.

Solder. A metallic composition used in joining together or *soldering* metals.

Solid. (Lat.) In geometry, a body which has length, breadth, and thickness; that is, it is terminated or contained under one or more plane surfaces, as a surface is under one or more lines. Regular solids are such as are terminated by equal and similar planes, so that the apex of their solid angles may be inscribed in a sphere.

Solid Angles. An angle formed by three or more angles in a point, and whereof the sum of all the plane angles is less than three hundred and sixty degrees, otherwise they would constitute the plane of a circle and not of a solid.

Solid Shoot. See Water Shoot.

Solive. The French term for a joist, rafter, or piece of wood, either slit or sawed, with which builders lay their ceilings. The term is rarely used in the English language.

Sommering. See Summering.

Sortant Angle. The same as Salient Angle, which see.

Sostratus. See Architects, list of, 25.

Soufflot. See Architects, list of, 299.

Sound-board. The same as a canopy or type over a pulpit, to reverberate the voice of the speaker.

Sound-boarding. In floors, consists of short boards placed transversely between the joists, and supported by fillets fixed to the sides of the latter for holding pugging, which is any substance that will prevent the transmission of sound from one story to another. The narrower the sound-boards the better. The fillets on which they rest may be about three-quarters of an inch thick and about an inch wide, nailed to the joists at intervals of a foot. See Boarding for Pugging.

Souse (Fr.) or **Source.** A support or under-prop.

Span. An imaginary line across the opening of an arch or roof, by which its extent is estimated.

SPAN ROOF. One consisting of two inclined sides, in contradistinction to *shed* or *leanto roofing*. It may be with simple rafters, with or without a collar beam, or when of increased span it may be trussed, the term only applying to the external part.

SPANDREL. The irregular triangular space between the outer curve or extrados of an arch, a horizontal line from its apex, and a perpendicular line from its springing.

SPANDREL BRACKETING. A cradling of brackets fixed between one or more curves, each in a vertical plane, and in the circumference of a circle whose plane is horizontal.

SPANISH ARCHITECTURE. See Book I. Chap. II. Sect. 19.

SPAR-PIECE. A name given in some places to the collar beam of a roof.

SPARS. The common rafters of a roof for the support of the tiling or slating.

SPECIFICATION. A description at length of the materials and workmanship to be used and employed in the erection of any building. See Book II. Chap. III. Sect. 13.

SPECIFIC GRAVITY. A gravity or weight of every solid or fluid compared with the weight of the same magnitude of rain water, which is chosen as the standard of comparison, on account of its being subject to less variation in different circumstances of time, place, &c., than any other solid or fluid. By a fortunate coincidence, at least to the English philosopher, it happens that a cubic foot of rain water weighs 1000 ounces avoirdupois; consequently, assuming this as the specific gravity of rain water, and comparing all other bodies with this, the same numbers that express the specific gravity of bodies will at the same time express the weight of a cubic foot of each in avoirdupois ounces, which affords great facility to numerical computations. Hence are readily deduced the following laws of the specific gravity of bodies: —

1. In bodies of equal magnitudes the specific gravities are directly as the weights or as their densities. 2. In bodies of the same specific gravities the weights will be as the magnitudes. 3. In bodies of equal weights the specific gravities are inversely as the magnitudes. 4. The weights of different bodies are to each other in the compound ratio of their magnitudes and specific gravities.

Thus it is obvious, that if of the magnitude, weight, and specific gravity of a body any two be given, the third may be found; and we may thus arrive at the magnitude of bodies which are too irregular to admit of the common rules of mensuration; or, by knowing the specific gravity and magnitude, we may find the weight of bodies which are too ponderous to be submitted to the action of the balance or steel yard; or, lastly, the magnitude and weight being given, we may ascertain their specific gravities.

TABLE OF SPECIFIC GRAVITIES

(Extracted from Davies, Lavoisier, Young, and other authentic sources).

Note. — Water at 60° is assumed 1000 specific gravity.

Mineral Productions.

Platina, purified	19500	Garnet, Bohemian	4188
———, hammered	20336	Sapphire of Pay	4076
Pure gold, cast	19258	Topaz, oriental	4010
————, hammered	19361	Beryl, or oriental aquamarine	3548
Mercury	13568	Diamond, rose-coloured	3531
Lead, cast	11352	————, white	3521
Silver, pure, cast	10474	————, lightest	3501
—————, hammered	10510	Glass, flint	3329
Bismuth, cast	9822	——, white	2892
Copper, cast	8788	——, bottle	2732
———, wire,	8878	——, green	2642
Brass, cast	8395	Fluor	3191
——, wire	8544	Serpentine, green	2988
Cobalt, cast	7812	Mica, black	2900
Nickel, cast	7807	Basalt, from the Giant's Causeway	2864
Iron, cast	7207	Marble, white Parian	2837
——, bar	7788	Marble, green	2741
Steel, hard, not screwed	7816	———, red	2725
——, soft, not screwed	7833	———, white, of Carrara	2716
Loadstone	4800	Emerald, Peruvian	2775
Tin, cast	7291	Porphyry, red	2765
Zinc, cast	7190	Jaspar	2764
Antimony, cast	6702	Alabaster, white	2730
Tungstein	6066	Calcareous spar, rhombic	2715
Arsenic, cast	5763	—————, pyramidal	2714
Molybdena	4738	Slate	2671
Spar, ponderous	4430	Pitch stone	2669
Ruby, oriental	4283	Onyx, pebble	2664

Chalcedony, transparent	2664	Lapis obsidianus	2348
Granite, Egyptian, red	2654	Selenite	2322
Rock chrystal, pure	2653	Grindstone	2142
Amorphous quartz	2647	Salt	2130
Agate, onyx	2637	Sulphur, native	2033
Cornelian	2613	Nitre	2000
Sardonyx	2602	Brick	2000
Purbeck stone	2601	Plumbago	1860
Flint, white	2594	Alum	1720
——, blackish	2581	Asphaltum	1400
Agate, oriental	2590	Coal, Scotch	1300
Portland stone	2570	——, Newcastle	1270
Mill stone	2483	——, Staffordshire	1240
Paving stone	2415	Jet	1238
Touchstone	2415	Ice, *probably*	930
Porcelain, Chinese	2384	Pumice-stone	914

Liquids.

Sulphuric acid	1840	Sea Water	1026
————, Ph., London	1850	Muriatic acid	1194
Nitrous acid, Ph., London	1550	Water of the Seine, filtered	1001
Nitric acid	1217	Naphtha	708

Vegetable Productions.

Sugar, white	1606	Vinegar, distilled	1009
Gum Arabic	1452	Water at 60°	1000
Pitch	1150	Bordeaux wine	994
Malmsey, Madeira	1038	Turpentine, liquid	991
Cider	1018	Linseed oil	940

Animal Substances.

Pearl	2750	Milk, cow's	1032
Coral	2680	Wax, white	968
Sheep's bones, recent	2222	——, yellow	965
Oyster shell	2092	Spermaceti	943
Ivory	1917	Butter	942
Stag's horn	1875	Tallow	942
Ox's horn	1840	Lamp oil	923

Woods.

Pomegranate tree	1354	Maple	755
Lignum Vitæ	1333	Cherry tree	715
Box, Dutch	1328	Quince tree	705
Ebony	1177	Orange tree	705
Heart of oak, 60 years felled	1170	Walnut	671
Oak, English, just felled	1113	Pitch pine	660
————, seasoned	743	Red pine	657
————, usually stated at	925	Yellow pine	529
Bog oak of Ireland	1046	White pine	420
Teak of the East Indies	745 to 657	Fir of New England	553
Mahogany	1063 to 637	— of Riga	753
Pear tree, trunk	646	— of Mar Forest, Scotland	696
Medlar tree	944	Cypress	644
Olive wood	927	Lime tree	604
Logwood	931	Filbert wood	600
Beach	852	Willow	585
Ash	845 to 600	Cedar	560
Yew, Spanish	807	Juniper	556
——, Dutch	788	Poplar, white Spanish	529
Alder	800	———, common	383
Elm	800 to 600	Sassafras wood	482
Apple tree	793	Larch of Scotland	530
Plum tree	755	Cork	240

Specus. (Lat.) In ancient architecture, the canal into which the water flowed in aqueducts raised above the surface of the ground, and constructed of hewn stones or bricks. It was covered with a vault to preserve the water from the sun, and from being mixed with rain water. The specus was sometimes covered with flat stones, laid horizontally, as in the Aqua Martia, part of the Aqua Claudia, and the aqueduct of Segovia. Sometimes the same arcade carried several of these canals one above the other.

Sphæristerium. A building for the exercise of the ball; a tennis court. The ancients generally placed sphæristeria among the apartments of their baths and gymnasia. They were also placed in large villas, as in those of Pliny the younger.

Sphere. (Gr. Σφαιρα.) A solid, whose surface is at every point equally distant from a certain point within the solid, which point is called the *centre of the sphere*. Every sphere is equal to two-thirds of its circumscribing cylinder, that is, it is equal to a cylinder whose ends are circles, equal to a great circle of the sphere, and whose height is equal to the diameter of the same.

Spherical Bracketing. That so formed that the surface of the plastering which it is to receive forms a spherical surface.

Spheroid. See Conoid.

Spheroidal Bracketing. That formed to receive the plastering of a spheroid.

Spina. See Circus.

Spintharus. See Architects, list of, 9.

Spiral. A curve which makes one or more revolutions round a fixed point, and does not return to itself.

Spire. (Gr. Σπειρα, a twisting.) In ancient architecture, the base of a column, and sometimes the astragal or torus; but among the moderns it designates a steeple diminishing as it ascends, either pyramidally or conically.

Splayed. A term applied to whatever has one side making an oblique angle with the other: thus, the heading joists of a boarded floor are frequently splayed in their thickness; as are also the jambs or sides of a window. In the latter case, the practice is for the better lighting of a room. The word *fluing* is sometimes applied to an aperture, in the same sense as *splayed*.

Spring Bevel of a Rail. The angle made by the top of the plank, with a vertical plane touching the ends of the railpiece, which terminates the concave side.

Springed. In boarding a roof, the setting the boards together with bevel joints, for the purpose of keeping out the rain.

Springer. The impost or place where the vertical support to an arch terminates, and the curve of the arch begins; the term is sometimes used for the *rib* of a groined roof.

Springing Course. The horizontal course of stones, from which an arch springs or rises; or that row of stones upon which the first arch stones are laid.

Square. (Lat. Quadra.) A figure of four equal sides, and as many equal angles; also, an area of such form surrounded by houses, and ornamented in the centre with a lawn, shrubs, trees, &c. In joinery, a work is said to be *square framed*, or *framed square*, when the framing has all the angles of its styles, rails, and mountings square without being moulded. The word is also applied to an instrument for setting out angles square. See Carpenter's Square.

Square Shoot. A wooden trough for discharging water from a building.

Square Staff. A piece of wood placed at the external angle of a projection in a room to secure the angle, which if of plaster would be liable to be broken, and at the same time to allow a good finish for the papering.

Squaring a Handrail. The method of cutting a plank to the form of a rail for a staircase, so that all the vertical sections may be right angles.

Squaring a Piece of Stuff. The act of trying it by the square, to make the angles right angles.

Stable. (Lat.) A building for the accommodation of horses.

Stack of Chimneys. See Chimney.

Stadium. (Gr.) In ancient architecture, an open space wherein the athleti or wrestlers exercised running, and in which they contested the prizes. It signifies also the place itself where the public games were celebrated, often formed a part of the gymnasia. The word also denotes a measure of length among the Grecians, of 125 paces.

Staff-bead. See Angle-bead.

Stage. A floor or story. In a theatre, the floor on which the performers act. The stage of a buttress is, in ecclesiastical architecture, the part between one splayed projection and the next.

Stair. (Sax. Stæᵹeꞃ, to step.) A stone, or piece of other material, by which a person raises himself one step. A series of steps or stairs for ascending from the lower to the upper part of a building, when enclosed by a wall, is called a staircase.

Staircase. That part or subdivision in a building containing the stairs, which enable persons to ascend or descend from one floor to another. See Book III. Chap. I. Sect. 23, for its construction.

Stalk. (Sax.) An ornament in the Corinthian capital, which is sometimes fluted, and resembles the stalk of a plant; from it spring the volutes and helices.

Stall. (Sax.) A place or division in a stable wherein one horse is placed for feeding and sleeping. According to their number in a stable it is called a one-stall, two-stall, &c. stable. This word is also used to denote an elevated seat in the choir or chancel of a church appropriated to an ecclesiastic, such as the prebendal stall of a cathedral.

Stanchion. (Fr. Estançon.) A prop or support. The upright mullions or bars of a window or open screen. Also a Punchion, which see.

Standards. The upright pieces in a plate rack, or above a dresser, to support the shelves thereover.

When the edges of standards are cut into mouldings across the fibres of the wood they are called *cut standards*.

Staple. A small piece of iron pointed at each end, and bent round, so that the two ends may be parallel to each other, and of equal lengths, to be driven into wood or into a wall, thus forming a loop for fastening a hasp or bolt.

Starlings or Sterlings, sometimes called Stilts. An assemblage of piles driven round the piers of a bridge to give it support.

Statics. See Mechanics.

Statuary Marble. See Book II. Chap. II. Sect. 3.

Staves. Small upright cylinders, sometimes called *rounds*, for forming a rack to contain the hay in stables for the supply of it to the horses.

Stay. A piece performing the office of a brace, to prevent the swerving of the piece to which it is applied. The term is general, and applies to all materials.

Steel. (Sax. Stal.) Iron united with carbon, which is accomplished in two ways, by fusion and by cementation; the former is used to convert iron into steel immediately from the ore, or from crude or cast-iron; the last-named process is effected by exposing iron, covered with charcoal, to a strong continued heat. The process for converting iron into steel was known to the ancients.

Steening. The brickwork laid dry used for forming the cylindrical shaft of a well or cesspool, whose office is to prevent the irruption of the surrounding soil.

Steeple. (Sax. Stepel.) A lofty erection attached to a church, chiefly intended to contain its bells. The word is a general term, and applies to every appendage of this nature, whether tower or spire, or a combination of the two.

Steps. The same as Stair, which see.

Stereobata. See Pedestal.

Stereographic Projection. That projection of the sphere wherein the eye is supposed to be placed on the surface.

Stereography. (Gr. Στερεος, solid, and Γραφω, I describe.) That branch of solid geometry which demonstrates the properties and shows the construction of all regularly defined solids; it explains the methods for constructing the surfaces on planes, so as to form the entire body itself, or to cover its surface; or, when the solid is bounded by plane surfaces, the inclination of the planes.

Stereotomy. The science of cutting solids to suit certain conditions required for their forms.

Stile. (Sax.) The vertical part of a piece of framing into which, in joinery, the ends of the rails are fixed by mortises and tenons; the tenon has the name, where, in other material than wood, any imitation of framing appears.

Stilts. See Starlings.

Stoa. (Gr.) In Grecian architecture, a term corresponding with the Latin *porticus*, and the Italian *portico*.

Stock. The part of a tool for boring wood with a crank whose end rests against the breast of the workman, while with one hand he holds the boring end steady, and with the other turns the crank; the steel borers are called *bits*, and the whole instrument is called a *stock and bit*.

Stone. (Sax.) A natural indurated substance found beneath and on the surface of the earth in almost every part of the world, and which for its strength and durability has been universally employed for building purposes. See Book II. Chap. II. Sect. 1.

Stoothings. A provincial term which signifies the battening of walls.

Stop-cock. A cock used in plumbery to turn off the supply to a reservoir.

Story. (Lat. or Sax. Stoꞃ.) One of the vertical divisions of a building; a series of apartments on the same level.

Story Posts. Upright timbers disposed in the story of a building for supporting the superincumbent part of the exterior wall through the medium of a beam over them; they are chiefly used in sheds and workshops, and should have either a solid wall below or stand upon a strong wooden sill upon inverted arches, or upon large stones, with their ends let into sockets.

Story Rod. One used in setting up a staircase, equal in length to the height of the story;

and divided into as many parts as there are intended to be steps in the staircase, so that they may be measured and distributed with accuracy.

Straight Joint Floor. See Floor.

Strain. (Sax. Stꞃenᵹ.) The force exerted on any material tending to disarrange or destroy the cohesion of its component parts.

Straining Piece or Strutting Piece. A beam placed between two opposite beams to prevent their nearer approach, as rafters, braces, struts, &c. If such a piece serves also the office of a sill, it is called a *straining sill*.

Strap. (Dutch, Stroppe.) An iron plate for the connection of two or more timbers, whereinto it is screwed by bolts.

Strength of Materials. See Book II. Chap. I. Sect. 11.

Stretched out. A term applied to a surface that will just cover a body so extended that all its parts are in a plane, or may be made to coincide with a plane.

Stretcher. A brick or stone laid with its longer face in the surface of the wall.

Stretching Course. In walling, a course of stones or bricks laid with their longer dimensions in a horizontal line parallel to the face of the wall; it is exactly the contrary of a *heading course*, in which the breadths of the stones or bricks are laid in a straight line parallel to the face of the wall.

Striæ. (Lat.) The lists or fillets between the flutes of columns.

Striated. Champered or channeled.

Striges. The channels of a fluted column.

Striking. A term used to denote the draught of lines on the surface of a body; the term is also used to denote the drawing of lines on the face of a piece of stuff for mortises, and cutting the shoulders of tenons. Another application of the word occurs in the practice of joinery, to denote the act of running a moulding with a plane. The *striking of a centre* is the removal of the timber framing upon which an arch is built, after its completion.

String or String Piece. That part of a flight of stairs which forms its ceiling or sofite.

String Board. In wooden stairs, the board next the well-hole which receives the ends of the steps; its face follows the direction of the well-hole, whatever the form: when curved, it is frequently formed in thicknesses glued together, though sometimes it is got out of the solid, like a hand-rail.

Strix. (Lat.) A channel in a fluted column.

Struck. A term used to denote the removal of any temporary support in a building during its execution.

Strut. See Brace.

Strutting Beam or Strut Beam. A term used by old writers in carpentry, for what is now called a *straining* or *collar beam*.

Strutting Piece. The same as Straining Piece, which see; and also Bridgings and Keys.

Stucco. (Fr. Stuc.) A term indefinitely applied to calcareous cements of various descriptions.

Studs. (Sax.) The quarters or posts in partitions. The term is used chiefly in the provinces.

Stuff. (Dutch.) A general term for the wood used by joiners.

Stylobata. See Pedestal.

Subdivision and Apartments of a Building. See Book III. Chap. II. Sect. 5.

Subnormal. The distance between the foot of the ordinate and a perpendicular to the curve (or its tangent) upon the axis.

Sub-plinth. A second and lower plinth placed under the principal one in columns and pedestals.

Sub-principals. The same as auxiliary rafters or principal braces.

Sudatio. (Lat.) See Concamerata Sudatio.

Suger. See Architects, list of, 96.

Summer. The lintel of a door, window, &c. A beam tenoned into a girder to support the ends of joints on both sides of it. It is frequently used as a synonyme for a girder. Also a large stone laid over columns and pilasters in the commencement of a cross vault. It is, moreover, used in the same sense as Bressummer, which see.

Summer Tree. See Dormant Tree.

Summering. See Beds of a Stone.

Sunk Shelves. Such as are formed with a groove in them to prevent the plates, dishes, or other materials sliding off their upper surface.

Superstructure. (Lat.) The work built on the foundation of a building. The upper part.

Support. See Points of Support.

Surbase. The series of mouldings immediately above the base of a room.

Swallow-tailed. See Dove-tailed.

Swedish Timber. See p. 485.

Sycamore. The *acer pseudo-platanus*, a tree, whose wood is much used by turners. See p. 486.

Syenite. A stone which consists of feldspar and hornblende, of various colours, as reddish, dull green, &c., as the feldspar or hornblende may predominate. It obtained the name from its abundance of syene, and according to Pliny was at first named *pyropœcilos*. It is, in fact, a species of granite, and was the material used for Pompey's Pillar.

Symmetry. (Gr. Συν, with, and Μετρω, I measure.) A system of proportion in a building, from which results from one part the measurement of all the rest. It also conveys the meaning of uniformity as regards the answering of one part to another.

Systyle. (Gr.) See Colonnade.

T.

Tabern. A provincial term for a cellar.

Tabernacle. (Lat.) In Catholic churches the name given to a small representation of an edifice placed on the altar for containing consecrated vessels, &c.

Table. In perspective, the same as the plane of the picture, being the paper or canvas on which a perspective drawing is made, and usually perpendicular to the horizon. In the theory of perspective, it is supposed to be transparent for simplifying the theory.

Table or Tablet. (Lat. Tabula.) A flat surface generally charged with some ornamental figure. The outline is generally rectangular, and when raised from the naked of the wall, is called a *projecting* or *raised table*. When not perpendicular to the horizon, it is called a *raking table*. When the surface is rough, frosted, or vermiculated, from being broken with the hammer, it is called a *rusticated table*.

Table, Corbel. See Corbel Table.

Table of Glass. In glass works and among glaziers, a circular plate of glass, being its original form before it is cut or divided into squares. Twenty-four tables make a *case*.

Table, Water. An inclined plane where a wall sets off to a smaller projection, for the purpose of throwing off the water, principally used in buttresses and other parts of Gothic edifices.

Tablet. The same as Table.

Tabling. A term used by the Scotch builders to denote the coping of the walls of very common houses.

Tablinum. (Lat.) In Roman architecture, an apartment situated in the narrow part of the atrium, as is supposed, fronting the entrance. Its exact position is not now known, and indeed the situation of it may, under circumstances, have varied, its true place therefore must be a matter of doubt.

Tabulatum. (Lat.) A term used by the Romans not only in respect to the floors, wainscottings, ceilings, &c., which were constructed of wood, but also to balconies and other projecting parts, which latter Vitruvius calls *projectiones*.

Tacks. Small nails used for various purposes, but principally for stretching cloth upon a board.

Tænia. (Gr.) The fillet which separates the Doric frieze from the architrave.

Tail. (Verb.) A term denoting the hold of any bearing piece on that which supports it, as where the end of a timber lies or *tails* upon the wall. The expression is similar to what in joinery is called *housing*, with this difference, that housing expresses the complete surrounding of the cavity of the piece which is let in.

Tail Bays. See Case Bays.

Tail Trimmer. One next the wall, into which the ends of joints are fastened, in order to avoid flues.

Tailing. The part of a projecting stone or brick inserted in a wall.

Tailloir. (Fr.) The name which the French give to the *abacus*.

Talon. (Fr.) The name given by the French to the *ogee*.

Tambour. (Fr. a drum.) A term denoting the naked ground on which the leaves of the Corinthian and Composite capitals are placed. It signifies also the wall of a circular temple surrounded with columns, and further the circular vertical part below a cupola as well as above it.

Tangent. (Lat. Tango.) A line drawn perpendicular to the extremity of the diameter of a circle, and therefore touching it only at one point. In trigonometry it is a line drawn perpendicularly from the extremity of the diameter, at one end of the arc, and bounded by a straight line drawn from the centre through the other.

Tapering. A term expressive of the gradual approach, as they rise, of the sides of a body to each other, so that if continued they would terminate in a point.

Tarras. See Book II. Chap. II. Sect. 10. It is a strong cement, useful in aquatic works.

Tassals. (Fr.) The pieces of timber lying under the mantel tree.

Taste. See p. 673. 676.

Tatti Sansovino. See Architects, list of, 229.

Tavellæ. (Lat.) Bricks in ancient Roman architecture which were seven inches long and three and a half broad.

Taxis. (Gr.) A term used by Vitruvius to signify that disposition which assigns to every part of a building its just dimensions. Modern architects have called it *ordonnance*.

Taylor, Sir Robert. See **Architects**, list of, 302.

Teaze Tenon. A tenon on the top of a post, with a double shoulder and tenon from each, for supporting two level pieces of timber at right angles to each other.

Tectorium Opus. (Lat.) A name in ancient architecture given to a species of plastering used on the walls of their apartments.

Telamones. (Gr. Τλαω, to support.) Figures of men used in the same manner as Caryatides. They are sometimes called *atlantes*.

Temones. (Gr. Τεμνος.) The places in a temple where statues were placed.

Tempered. An epithet applied to bricks which may be cut with ease, and reduced with ease to a required form. The term is also applied to mortar and other cement, which has been well beaten and mixed together.

Templa. (Lat.) Timbers in the roof of the Roman temples, which rested on the *cantherii*, or principal rafters, similar to our purlins.

Template. An improper orthography for **Templet**, which see.

Temple. (Lat.) Generally an edifice erected for the public exercise of religious worship. The subject of temples has been so fully considered in the body of the work, under the different heads of Ancient, Grecian, and Roman Architecture, that we shall here confine ourselves to the description of the different species of temples mentioned by Vitruvius. The difference between temples is by that author thus given (book iii.): — A temple is said to be *in antis* when it has antæ or pilasters in front of the walls, which enclose the cells, with two columns between the antæ. A plan of such a temple is seen in *fig.* 1047.

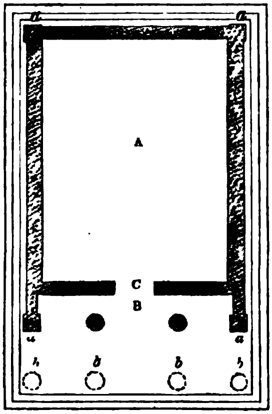

Fig. 1047.

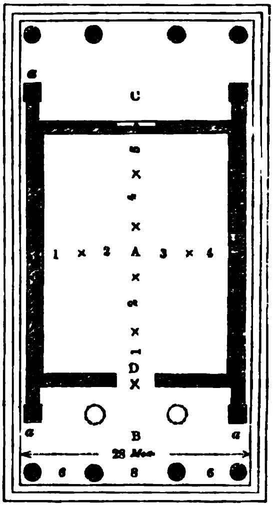

Fig. 1048.

It was crowned with a pediment, and was not dissimilar to the prostylos temple, to which we shall presently come. In the figure, A is the cell, *aa* the antæ, and if in front of them, the columns *bbbb* were placed, it would be a *prostyle* temple; C is the door of the cell, and B the pronaos. The appearance in front of this species is the same as the *amphiprostyle* temple, which is given in *fig.* 1048., and wherein columns are also placed in front of the antæ. Of the prostyle temple, an example, that of the temple of Jupiter and Faunus, existed on the island of the Tyber at Rome. In the figure of the amphiprostyle temple, A is the cell, B the pronaos, C the posticus, D the door of the cell, and *aa* are the antæ. It will be immediately seen that the same elevation will apply (*fig.* 1049.) to both the plans just given. The amphiprostyle temple, be it observed, has columns in the rear as well as in front, and is distinguished by that from the prostylos of *fig.* 1047., wherein the columns *bbbb* (*fig.* 1048.) would make that prostylos which, but for them, would be merely a temple in antis. The *amphiprostylos* then only differs from the *prostyle* by having columns in the rear, repeated similarly to those in the front. The *fig.* 1049.

applies on double the scale of the plan to both *figs.* 1047. and 1048., and is a diastyle tetrastyle temple, that is, one whose intercolumniations (see Colonnade) are of three diameters, and the number of whose columns is four.

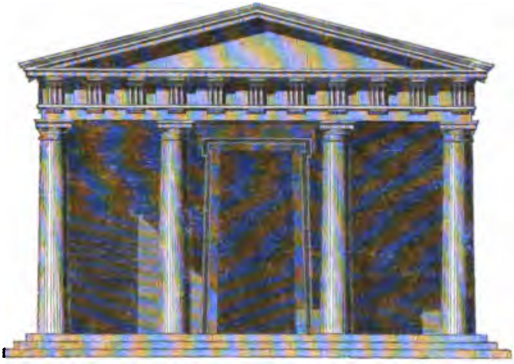

Fig. 1049.

A *peripteral temple* had six columns in front and rear, and eleven on the flanks, counting the two columns on the angles (see *fig.* 1050.), and these were so placed that their distance from the wall was equal to an intercolumniation or space between the columns all round, and thus it formed a walk around the cell. In *fig.* 1051. is the elevation of

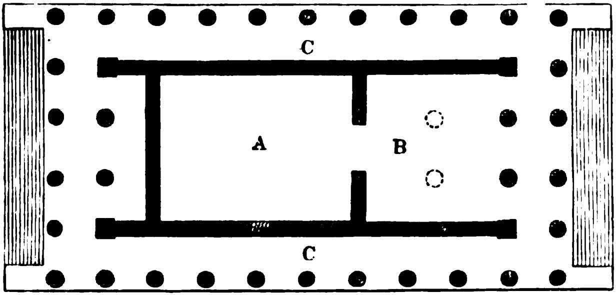

Fig. 1050.

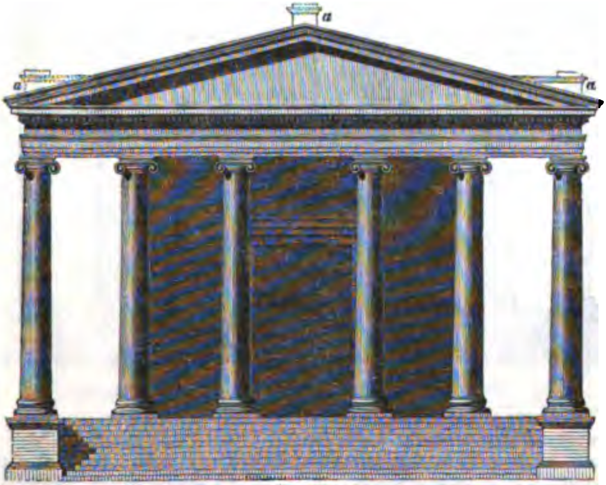

Fig. 1051.

the species, which is hexastyle and eustyle, that is, with six columns in front, whose intercolumniation is *eustyle*, or of two diameters and a quarter. (See Colonnade.) In this figure, which is to a double scale of the plan, *aaa* are *acroteria*.

The *pseudo-dipteral temple* was constructed with eight columns in front and rear, and with fifteen on the sides, including those at the angles, see *fig.* 1052. The walls of the cell are opposite to the four middle columns of the front and of the rear. Hence, from the walls to the front of the lower part of the columns, there will be an interval equal to two intercolumniations and the thickness of a column all round. No example existed of such a temple at Rome; but there was one to Diana, built by Hermogenes of Alabanda, in Magnesia, and that of Apollo by Menesthes. The dipteral temple (*fig.* 1053.) is octastylos like the former, and with a pronaos and posticum, but all round the cell are two ranks of columns: such was the temple of Diana, built by Ctesiphon. The elevation (*fig.* 1054.) is the same in the dipteral and pseudo-dipteral temple, and in the figure is with the systyle intercolumniation.

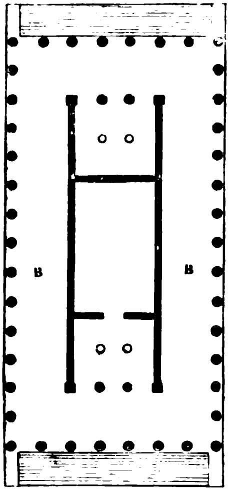

Fig. 1052.

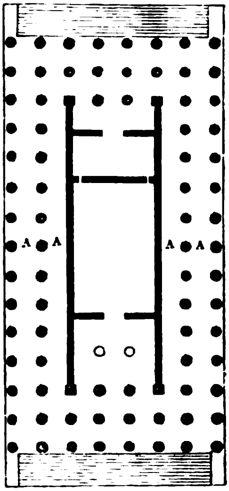

Fig. 1053.

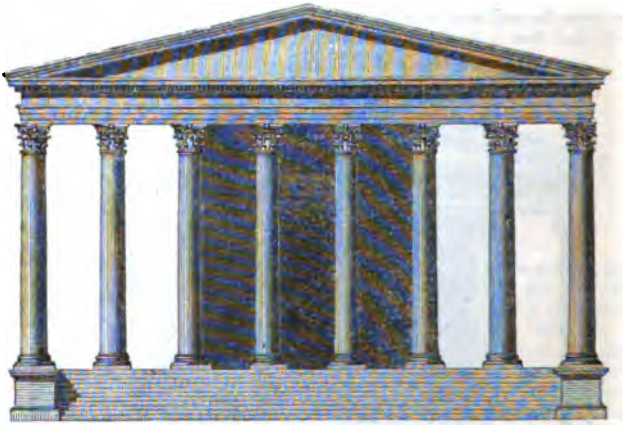

Fig. 1054.

The *hypæthral* temple, or that uncovered in the centre, is decastylos in the pronaos and posticum; it is in other respects (see *fig.* 1055.) similar to the dipteral, except that

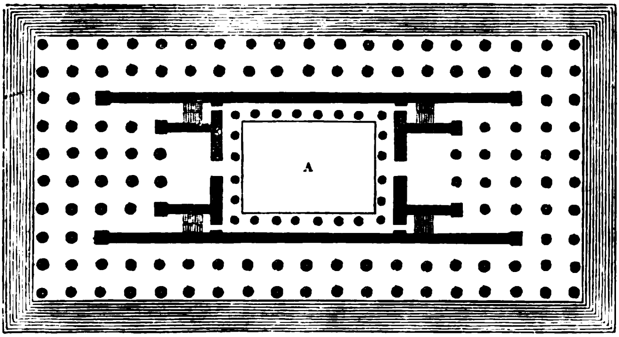

Fig. 1055.

in the inside it has two stories of columns all round, at some distance from the walls, after the manner of the peristylia of porticoes (see *fig.* 1056.), in which one half is the elevation and the other half the section of the temple.

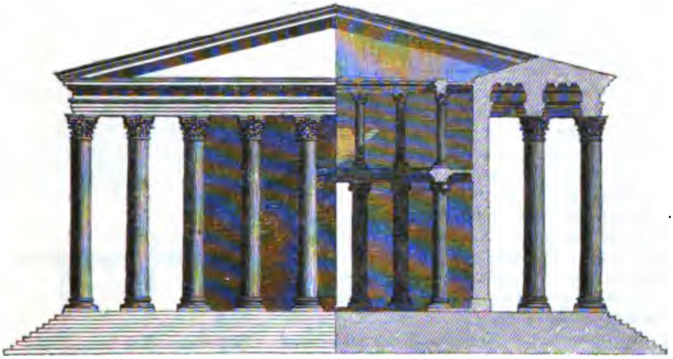

Fig. 1056.

We have described the peripteral temple, but there is still another connected with that species, though distinct, and that is the pseudo-peripteral, or false peripteral, in which there is no passage round the walls of the cell, but an appearance of surrounding columns (see *fig.* 1057.).

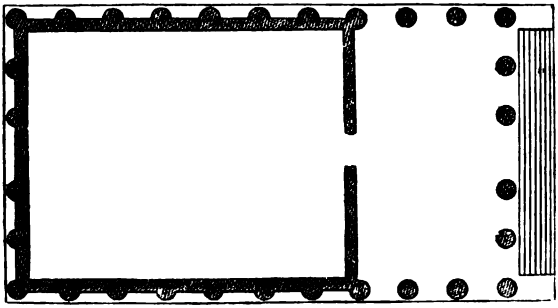

Fig. 1057.

By this arrangement more room was given to the space of the cell.

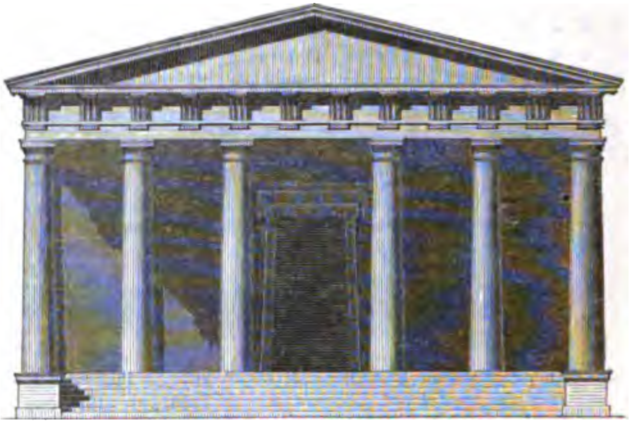

Fig. 1058.

The elevation of this is given in *fig.* 1058. Vitruvius thus describes, as follows, the proportions of the Tuscan temple:

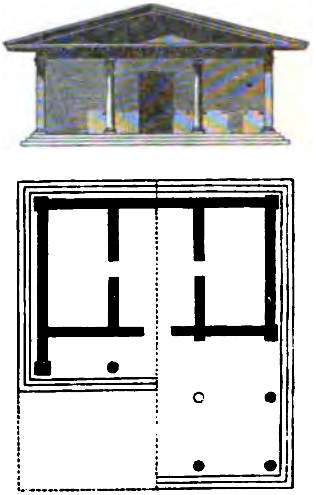

Fig. 1059.

The length of the site of the temple intended (see *fig.* 1059.) must be divided into six parts, whence, by subtracting one part, the width thereof is obtained. The length is then divided into two parts, of which the furthest is assigned to the cell, that next the front to the reception of the columns.

The above width is to be divided into ten parts, of which three to the right and three to the left are for the smaller cells, or for the alæ, if such are required; the remaining four are to be given to the central part. The space before the cells in the pronaos is to have its columns so arranged that those at the angles are to correspond with the antæ of the external walls: the two central ones opposite the walls between the antæ and the middle of the temple are to be so disposed, that between the antæ and the above columns, and in that direction, others may be placed.

Their thickness below is to be one-seventh of their height, their height one-third of the width of the temple, and their thickness at top is to be one-fourth less than their thickness at bottom. Their bases are to be half a diameter in height. The plinths, which are to be circular, are half the height of the base, with a torus and fillet on them as high as the plinth.

The height of the capital is to be half a diameter, and the width of the abacus equal to the lower diameter of the column. The height of the capital must be divided into three parts, whereof one is assigned to the plinth or abacus, another to the echinus, the third to the hypotrachelium, with its apophyge.

Over the columns coupled beams are laid of such height as the magnitude of the work may require. Their width must be equal to that of the hypotrachelium at the top of the column, and they are to be so coupled together with dovetailed dowels as to leave a space of two inches between them. Above the beams and walls the mutuli project one-fourth of the height of the columns. In front of these members are fixed, and over them, the tympanum of the pediment, either of masonry or timber.

Of circular temples there are two species; the monopteral (*fig.* 1060.) having columns without a cell, and the peripteral with a cell as in *fig.* 1061. In this last the clear diameter of the cell within the walls is to be equal to the height of the columns above the pedestal. Of this species was the celebrated temple at Tivoli, in the admiration whereof no dissentient from its allowed beauty has hitherto been recorded. With it situation has doubtless much to do.

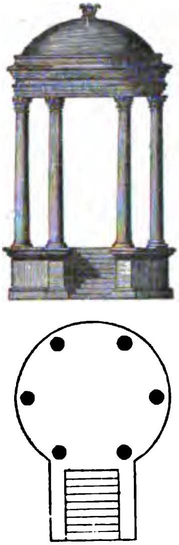

Fig. 1060.

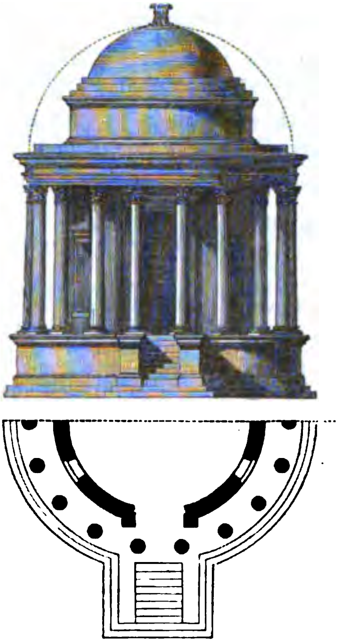

Fig. 1061.

Templet. A mould used in masonry and brickwork for the purpose of cutting or setting out the work. When particular accuracy is required, two templets should be used, one for moulding the end of the work, and its reverse for trying the face. When many stones or bricks are required to be wrought with the same mould, the templets ought to be made of copper.

The term is also used to denote a short piece of timber sometimes laid under a girder, particularly in brick buildings.

Tenon. (Fr. Tenir.) A projecting rectangular prism formed on the end of a piece of timber to be inserted into a mortise of the same form.

Tenon Saw. One with a brass or steel back for cutting tenons.

Tension. The stretching or degree of stretching to which a piece of timber or other material is strained by drawing it in the direction of its length.

Teocopoli. See **Architects**, list of, 231.

Tepidarium. (Lat.) A name given to one of the apartments of a Roman bath.

Term or **Terminus.** A sort of trunk, pillar, or pedestal often in the form of the frustum of an inverted obelisk with the bust of a man, woman, or satyr on the top.

Terra Cotta. (It.) Baked or burnt earth, frequently used at an early period for the architectural decoration of a building. In the time of Pausanias there were in many temples statues of the deities made of this material. Bassi rilievi of terra cotta were frequently employed to ornament the friezes of temples. In modern times it has also been much used for architectural decoration, being plastic at first, easily worked, solid, and not expensive.

Terrace. An area raised before a building above the level of the ground to serve as a walk. The word is sometimes but improperly used to denote a balcony or gallery.

Tesselated Pavement. A rich pavement of Mosaic work made of small square marbles, bricks, tiles, or pebbles, called *tessela* or *tesseræ*.

Tessera. (Gr.) A cube or die. This name was, for what reason we are at a loss to conceive, applied to a composition used some years ago for covering flat roofs, but now, from its failure, quite abandoned.

Testudo. (Lat.) A name given by the ancients to a light surbased vault with which they ceiled the grand halls in baths and mansions. Generally, any arched roof.

Tetradoron. (Gr.) A species of brick four palms in length.

Tetragon. (Gr.) A figure which has four sides and as many angles.

Tetraspastos. (Gr. Τετρα, four, and Σπασσω, to draw). A machine working with four pulleys.

Tetrastyle. (Gr. Τετρα, and Στυλος, a column.) See Colonnade.

Thatch. The covering of straw or reeds used on the roofs of cottages, barns, and such buildings.

Theatre. (Gr. Θεαομαι, to see.) A place appropriated to the representation of dramatic spectacles. In respect of the ancient theatres see page 71.; and of modern theatres, Book III. Chap. III. Sect. 16.

Theodolite. An instrument used in surveying for taking angles in vertical or horizontal planes.

Theodorus. See Architects, list of, 1.

Theorem. A proposition which is the subject of demonstration.

Thermæ. See Bath.

Thomas of Canterbury. See Architects, list of, 138.

Thorough Framing. The framing of doors and windows, a term almost obsolete.

Thorough lighted Rooms. Such as have windows on opposite sides.

Threshold of a Door. The sill of the door frame.

Throat. See Gorge and Chimney.

Thrust. The force exerted by any body or system of bodies against another. Thus the thrust of an arch is the power of the arch stones considered as a combination of wedges to overturn the abutments or walls from which the arch springs.

Thynne. See Architects, list of, 235.

Tie. (Sax. Tian, to bind.) A timber-string, chain, or iron rod connecting two bodies together, which have a tendency to diverge from each other, such as tie-beams, diagonal ties, truss-posts, &c. Braces may act either as ties or straining pieces. Straining pieces are preferable to ties, for these cannot be so well secured at the joints as straining pieces.

Tie (Angle). See Angle Brace.

Tie Beam. The beam which connects the bottom of a pair of principal rafters, and prevents them from thrusting out the wall.

Tierce Point. The vertex of an equilateral triangle. Arches or vaults of the third point, which are called by the Italians *di terzo acuto*, are such as consist of two arcs of a circle intersecting at the top.

Tietlandus. See Architects, list of, 72.

Tige. (Fr.) A term used by the French, signifying the shaft of a column.

Tile. (Sax. Tiᵹel.) A thin piece or plate of baked clay or other material used for the external covering of a roof. See Book II. Chap. III. Sect. 9. In ancient buildings two forms of tiles were used. The imbrex, placed in regular rows to receive the shower, and the tegula, which covered and prevented the rain from penetrating the joints. The latter were fixed at the eaves with upright ornamental pieces called antefixæ, which were also repeated along the ridge at the junction of the tiles. The present common tiles of Italy are on this principle, and are shown by *fig.* 1062.

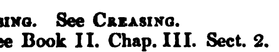

Fig. 1062.

Tile Creasing. See Creasing.

Tiling. See Book II. Chap. III. Sect. 2.

Timber. (Sax. Timbrian, to build.) Properly denotes all such wood, either growing or cut down, as is suited to the purposes of building. A single piece of wood, similarly employed, is so called as one of the *timbers* of a floor, roof, &c. See Book II. Chap. II. Sect. 4.

Tiodas. See Architects, list of, 73.

Tomb. (Gr. Τυμβος.) A grave or place for the interment of a human body, including also any commemorative monument raised over such a place. The word embraces every variety of grave and sepulchral monument, from the meanest grave to the most sumptuous mausoleum.

Tondino. (It.) Same as Torus, which see.

Tongue. See Groove.

Tools. (Sax.) Instruments used by artificers for the reduction of any material to its intended form. An account of those used by each set of workmen will be found under each department in Book II. Chap. III.

Tooth. The iron or steel point in a gage which marks the stuff in its passage, or draws a line parallel to the arris of the piece of wood.

Toothing. A projecting piece of material which is to be received into an adjoining piece. A tongue or series of tongues.

Top Beam. The same as Collar Beam, which see.

Top Rail. The uppermost rail of a piece of framing or wainscotting, as its name imports.

Torsel. The same as Tassel, which see.

Torsion. The twisting strain on any material.

Torus. (Lat.) A large moulding whose section is semicircular, used in the bases of columns. The only difference between it and the astragal is in the size, the astragal being much smaller.

Tower. (Sax.) A lofty building of several stories, round or polygonal.

Town Hall. A building in which the affairs of a town are transacted. See Book III. Chap. III. Sect. 7.

Trabeation. Another term for Entablature.

Trabs. The Latin term for a wall-plate.

Tracery. In Gothic architecture, the intersection, in various ways, of the mullions in the head of a window, the subdivisions of groined vaults, &c.

Trammel. An instrument for describing an ellipsis by continued motion.

Transept (quasi, transseptum). The transverse portion of a cruciform church; that part which is placed between and extends beyond those divisions of the building containing the nave and choir. It is one of the arms projecting each way on the side of the stem of the cross.

Transom. A beam across a window of two lights in height. If a window have no transom it is called a clear story window.

Transtra. (Lat.) The horizontal timbers in the roofs of ancient Roman buildings.

Transverse. Lying in a cross direction. The *transverse strain* of a piece of timber is that sidewise, by which it is more easily bent or broken than when compressed or drawn as a tie in the direction of its length.

Trapezium. (Gr.) In geometry, a quadrilateral figure whose four sides and angles are unequal, but two of its sides parallel.

Traverse. A gallery or loft of communication in a church or other large building.

Tread of the Step of a Stair. The horizontal part of it.

Trefoil. In Gothic architecture, an ornament consisting of three cusps in a circle.

Trellice. A reticulated framing made of thin bars of wood for screens; windows where air is required for the apartment, &c.

Tressel or Trussel. Props for the support of any thing, the under surface of which is horizontal. Each trussel consists of three or four legs attached to a horizontal part. When the tressels are high the legs are sometimes braced. Tressels are much used in building for the support of scaffolding, and by carpenters and joiners for ripping and cross-cutting timber, and for many other purposes.

Triangle. (Lat.) A plane rectilineal figure of three sides, and consequently of three angles. In measuring, all rectilineal figures must be reduced to triangles, and in constructions for carpentry all frames of more than three sides must be reduced to triangles to prevent a revolution round the angles.

Triangular Compasses. Such as have three legs or feet by which any triangle or any three points may be taken off at once.

Triclinium. (Lat.) The room in the Roman house wherein the company was received, and seats placed for their accommodation. It was raised two steps from the peristyle, and had therein a large window, which looked upon the garden. The aspect of winter triclinia was to the west, and of summer triclinia to the east. See p. 102.

Triforium. (Lat.) The gallery or open space between the vaulting and the roof of the aisles of a church, generally lighted by windows in the external wall of the building, and opening to the nave, choir, or transept over the main arches. It occurs only in large churches, and is varied in the arrangement and decoration of its openings in each succeeding period of architecture.

Triglyph. (Gr. Τρεις, and Γλυφη, a channel.) The vertical tablets in the Doric frieze chamfered on the two vertical edges, and having two channels in the middle, which are double channels to those at the angles. In the Grecian Doric, the triglyph is placed upon the angle; but, in the Roman, the triglyph nearest the angle is placed centrally over the column.

Trigonometry. (Gr. Τρεις, three, Γωνια, an angle, and Μετρω, I measure.) The science of determining the unknown parts of a triangle from certain parts that are given. It is either *plane* or *spherical*; the first relates to triangles composed of three right lines, and the second to triangles formed upon the surface of a sphere by three circular arcs. This latter is of less importance to the architect than the former, which is, for his purpose, sufficiently explained in Book II. Chap. I. Sect. 14.

Trilateral. (Lat.) Having three sides.

Trim. (Verb.) To fit to any thing; thus, to *trim up*, is to fit up.

Trimmed. A piece of workmanship fitted between others previously executed, which is then said to be *trimmed in* between them. Thus, a partition wall is said to be trimmed up between the floor and the ceiling; a post between two beams; a trimmer between two joists.

Trimmed out. A term applied to the trimmers of stairs when brought forward to receive the rough strings.

Trimmer. A small beam, into which are framed the ends of several joists. The two joists, into which each end of the trimmer is framed, are called *trimming joists*. This arrangement takes place where a well-hole is to be left for stairs, or to avoid bringing joists near chimneys, &c.

Trine Dimensions. Those of a solid, including length, breadth, and thickness; the same as threefold dimensions.

Tripod. (Gr. Τρεις, and Πους, a foot.) A table or seat with three legs. In architectural ornament its forms are extremely varied, many of those of the ancients are remarkable for their elegance and beauty of form.

Trisection. The division of any thing into three equal parts.

Trochilus. (Gr. Τροχιλος, a pulley.) An annular moulding whose section is concave, like the edge of a pulley. It is more commonly called a *scotia*, and its place is between the two tori of the base of a column.

Trochoid. (Gr. Τροχος a wheel, and Ειδος, shape.) A figure described by rolling a circle upon a straight line, such circle having a pin or fixed point in its circumference upon a fixed plane, in or parallel to the plane of the moving circle. It is also called a cycloid.

Trophonius. See Architects, list of, 3.

Trophy. (Gr. Τροπαιον.) An ornament representing the trunk of a tree charged with various spoils of war.

Trough. (Sax. Tꞃoh.) A vessel in the form of a rectangular prism, open on the top for holding water.

Trough Gutter. A gutter in the form of a trough, placed below the dripping eaves of a house, in order to convey the water from the roof to the vertical trunk or pipe by which it is to be discharged. It is only used in common buildings and outhouses.

Truncated. (Lat. Trunco, I cut short.) A term employed to signify that the upper portion of some solid, as a cone, pyramid, sphere, &c. has been cut off. The part which remains is called a *frustum*.

Trunk. That part of a pilaster which is contained between the base and the capital; also a vessel open at each end for the discharge of water, rain, &c.

Truss. (Fr. Trousse.) A combination of timber framing, so arranged, that if suspended at two given points, and charged with one or more weights in certain others, no timber would press transversely upon another except by timbers exerting equal and opposite forces. The principle of a truss is explained at p. 546.

Truss Partition. One containing a truss within it, generally consisting of a quadrangular frame, two braces, and two queen posts, with a straining post between them, opposite to the top of the braces.

Trussed Beam. One in which the combination of a truss is inserted between and let into the two pieces whereof it is composed.

Trussing Pieces. Those timbers in a roof that are in a state of compression.

Try. (Verb.) To plane a piece of stuff by the rule and square only.

Tube. (Lat.) A substance perforated longitudinally; generally quite through its length.

Tumbled in. The same as *trimmed in*. See Trimmed.

Tunnel. (Fr.) A subterranean channel for carrying a stream of water under a road, hill, &c.

Turning Piece. A board with a circular edge for turning a thin brick arch upon.

Turpentine. A resinous juice extracted from several trees belonging to the genus *Pinus*. All turpentine is obtained by exudation and hardening of the juice flowing from incisions into the pine trees. To obtain the oil of turpentine, the juice is distilled in an apparatus like the common still, and water is introduced with the turpentine.

Turret. (Lat. Turris.) A small tower often crowning the angle of a wall, &c.

Tuscan Order. See Book III. Chap. I. Sect. 3.

Tusk. A bevel shoulder made above a tenon, and let into a girder to give strength to the tenon.

Tympanum. (Gr.) The naked face of a pediment (see Pediment) included between the level and raking mouldings. The word also signifies the die of a pedestal, and the panel of a door.

Type. (Gr. Τυπος.) A word expressing by general acceptation, and consequently applicable to, many of the varieties involved in the terms model, matrix, impression, &c. It is, in architecture, that primitive model, whatever it may have been, that has been the foundation of every style, and which has guided, or is supposed to have guided, the forms and details of each. What it was in each style is still only conjecture, and forms the ground for the various observations on them in various parts of the body of this work.

Type. The canopy over a pulpit.

U.

Underpinning. Bringing a wall up to the ground sill. The term is also used to denote the temporary support of a wall, whose lower part or foundations are defective, and the bringing up new solid work whereon it is in future to rest.

Ungula. The portion of a cylinder or cone comprised by part of the curved surface, the segment of a circle, which is part of the base, and another plane.

University. An assemblage of colleges under the supervision of a senate, &c. See Book III. Chap. III. Sect. 8.

Uphers. Fir poles, from four to seven inches in diameter, and from twenty to forty feet in length. They are often hewn on the sides, but not entirely to reduce them square. They are chiefly used for scaffolding and ladders, and are also employed in slight and common roofs, for which they are split.

Upright. The elevation of a building; a term rarely used.

Uria, de. See Architects, list of, 209.

Urilla. See Helix.

Urn. (Lat.) A vase of a circular form, destined among the ancients to receive and preserve the ashes of the dead.

Ustamber. See Architects, list of, 80.

V.

Vagina. (Lat.) The lower part of a terminus in which the statue is apparently inserted.

Valdevira. See Architects, list of, 224.

Valerius of Ostia. See Architects, list of, 32.

Valley. (Lat.) The internal meeting of the two inclined sides of a roof. The rafter which supports the valley is called the *valley rafter* or *valley piece*, and the board fixed upon it for the leaden gutter to rest upon is called the *valley board*. The old writers called the valley rafters *sleepers*.

Valuations of Property. See Appendix, p. 882.

Valved. Any thing which opens on hinges.

Vanbrugh. See Architects, list of, 270.

Vane. A plate of metal shaped like a banner fixed on the summit of a tower or steeple, to show the direction of the wind.

Vanishing Line. In perspective, the intersection of the parallel of any original plane and the picture is called the vanishing line of such plane. The *vanishing point* is that to which all parallel lines in the same plane tend in the representation.

Vanvitelli. See Architects, list of, 291.

Variation of Curvature. The change in a curve by which it becomes quicker or flatter in its different parts. Thus, the curvature of the quarter of an ellipsis terminated by the two axes is continually quicker from the extremity of the greater axis to that of the lesser. There is no variation of curvature in the circle.

Varnish. A glossy coat on painting or the surface of any matter. It consists of different resins in a state of solution, whereof the most common are mastic, sandarac, lac, benzoin, copal, amber, and asphaltum. The menstrua are either expressed, or essential oils, or alcohol.

Vase. (Lat. Vas.) A term applied to a vessel of various forms, and chiefly used as an ornament. It is also used to denote the bell, or naked form, to which the foliage and volutes of the Corinthian and Composite capitals are applied. The *vases of a theatre* in ancient architecture were bell-shaped vessels placed under the seats to produce reverberation of the sound.

Vault. (It. Volto.) An arched roof over an apartment, concave towards the void, whose section may be that of any curve in the same direction. Thus a *cylindric vault* has its surface part of a cylinder. A *full-centred vault* is formed by a semi-cylinder. When a vault is greater in height than half its span, it is said to be *surmounted* when less *surbased*. A *rampant vault* springs from planes not parallel to the horizon. The *double vault* occurs in the case of one being above another. A *conic vault* is formed of part of the surface of a cone, as a *spherical vault* consists of part of the surface of a sphere. The plane of an *annular vault* is contained between two concentric circles. A vault is said to be *simple* when formed by the surface of some regular solid round one axis, and *compound* when formed of more than one surface of the same solid or of two different solids. A *cylindro-cylindric vault* is formed of the surfaces of two unequal cylinders: and a *groined vault* is a compound one rising to the same height in its surfaces as that of two equal cylinders, or a cylinder with a cylindroid. The *reins of a vault* are the sides or walls that sustain the arch. See the section on ARCHES, Book II. Chap. I. Sect. 9.

VELARIUM. (Lat.) The great awning which by means of tackle was hoisted over the theatre and amphitheatre to protect the spectators from the rain or the sun's rays.

VELLAR CUPOLA. A term used by Alberti to denote a dome or spherical surface terminated by four or more walls, frequently used over large staircases and salons, and other lofty apartments.

VENEER. A very thin leaf of wood of a superior quality for covering doors or articles of furniture which are made of an inferior wood.

VENETIAN DOOR. A door having side lights on each side for lighting an entrance hall.

VENETIAN WINDOW. One formed with three apertures separated by slender piers from each other, whereof the centre one is much larger than those on the sides.

VENT. The flue or funnel of a chimney; also any conduit for carrying off that which is offensive.

VENTIDUCT. A passage or pipe for the introduction of fresh air to an apartment.

VENTILATION. The continual supply of fresh air to an apartment, a subject which latterly has been considered so necessary, though much neglected as the moderns seem to think by their ancestors, that a volume would not hold the schemes that have been latterly proposed for that purpose. Generally it is enough for the architect to provide means for letting off the hot air of an apartment or building by apertures at the upper part of the rooms, &c., to which the hot air will ascend without afflicting with the currents of fresh air that are to be introduced those that inhabit them.

VERMICULATED. (Lat.) A term applied to rustic-work which is so wrought as to have the appearance of having been eaten into by worms.

VERTEX. (Lat. the top.) A term generally applied to the termination of any thing finishing in a point, thus we say the vertex of a cone, &c.

VERTICAL ANGLES. The opposite ones made by two straight lines cutting each other.

VERTICAL PLANE. One whose surface is perpendicular to the horizon.

VESTIBULE. (Lat. Vestibulum.) An apartment which serves as the medium of communication to another room or series of rooms. In the Roman houses it appears to have been the place before the entrance where the clients of the master of the house, or those wishing to pay their court to him, waited before introduction. It was not considered as forming a part of the house. The entrance from the vestibulum led immediately into the *atrium*, or into the cavædium.

VESTRY. (Lat. Vestiarium.) An apartment in, or attached to, a church for the preservation of the sacred vestments and utensils.

VICE. A term in old records applied to a spiral or winding staircase. In mechanics a machine serving to hold fast any thing worked upon, whether the purpose be filing, bending, riveting, &c.

VILLA. A country-house for the residence of an opulent person. Among the Romans there were three descriptions of villa, each having its particular destination, namely. The *Villa urbana*, which was the residence of the proprietor, and contained all the conveniences of a mansion in the city. The *Villa rustica*, which contained not only all that was essential to rural economy, such as barns, stables, &c., but comprised lodging apartments for all those who ministered in the operations of the farming establishment. The *Villa fructuaria* was appropriated to the preservation of the different productions of the estate, and contained the granaries, magazines for the oil, cellars for the wine, &c. See Book III. Chap. III. Sect. 22.

VINCI, DA. See ARCHITECTS, list of, 181.

VINERY. A house for the cultivation of vines. See CONSERVATORY.

VISORIUM. (Lat.) See AMPHITHEATRE.

VISUAL POINT. In perspective a point in the horizontal line in which the visual rays unite.

VISUAL RAY. A line of light supposed to come from a point of the object to the eye.

VITONI. See ARCHITECTS, list of, 168.

VITRIFICATION. The hardening of argillaceous stones by heat.

VITRUVIUS POLLIO. See ARCHITECTS, list of, 40.

VITRUVIUS CERDO. See ARCHITECTS, list of, 41.

VIVO. (Ital.) The shaft of a column.

VOLUTE. A spiral scroll which forms the principal feature of the Ionic and Composite capitals.

Vomitoria. (Lat.) See Amphitheatre.

Voussoir. (Fr.) A wedge-like stone or other matter forming one of the pieces of an arch. See Arch.

W.

Wagon-headed Ceiling. The same as cylindric ceiling. See Vault.

Wainscot. (Dutch, Wayschot.) A term usually applied to the wooden lining of walls in panels. The wood originally used for this purpose was a foreign oak (see p. 482.); hence the name of the material became attached to the work itself.

Walkelyn. See Architects, list of, 84.

Wall. A body of materials for the enclosure of a building and the support of its various parts. See Book II. Chap. I. Sect. 10.

Walls of the Ancients. *Emplecton*, *Isodomum*, *Pseudo-isodomum*. See Masonry.

Walls, cased. Those faced up anew round a building, in order to cover an inferior material, or old work gone to decay.

Walnut. A forest tree useful for building purposes. See p. 484.

Walsingham. See Architects, list of, 142.

Ware. See Architects, list of, 289.

Warren. See Architects, list of, 250.

Water-closet. See p. 583.

Water Shoot. See Square Shoot.

Water Table. See Table, Water.

Waynflete. See Architects, list of, 165.

Weather-boarding. See Boarding for outside Work.

Weather-tiling. The covering an upright wall with tiles.

Wedge. (Dan. Wegge.) An instrument used for splitting wood or other substances; it is usually classed among the mechanical powers. See p. 392.

Weight. (Sax. Wiht.) In mechanics, a quantity determined by the balance; a mass by which other bodies are examined. It denotes anything to be raised, sustained, or moved by a machine as distinguished from the power, or that by which the machine is put in motion.

Weight, in commerce, denotes a body of given dimensions, used as a standard of comparison for all others. By an act of parliament passed in June 1824, all weights were to remain as they then were, that act only declaring that the imperial standard pound troy shall be the unit or only standard measure of weight from which all other weights shall be derived and computed; that this troy pound is equal to the weight of 22·815 cubic inches of distilled water weighed in air at the temperature of 62° of Fahrenheit's thermometer, the barometer being at 30 inches, and that there being 5760 grains in a troy pound, there will be 7000 such grains in a pound avoirdupois.

Troy Weight.

24 grains = 1 pennyweight.
480 . . . = 20 . . . . = 1 ounce.
5760 . . . = 240 . . . . = 12 . . . = 1 pound.

Avoirdupois Weight.

16 drams = 1 ounce.
256 . . . = 16 . . . = 1 pound.
7168 . . . = 448 . . . = 28 . . . = 1 quarter.
28672 . . . = 1792 . . . = 112 . . . = 4 . . . . = 1 cwt.
573440 . . . = 35840 . . . = 2240 . . . = 80 . . . . = 20 . . = 1 ton.

The avoirdupois pound : pound troy :: 175 : 144, or :: 11 : 9 nearly; and an avoirdupois pound is equal to 1 lb. 2 oz. 11 dwts. 16 grains troy. A troy ounce = 1 oz. 1·55 dr. avoirdupois.

The following is a table of weights according to the new French system.

Names.	French value.		English value.
Millier,	1000 kilogrammes = 1 French ton -	=	19·7 cwts.
Quintal,	100 kilogrammes - - - - -	=	1·97 cwt.
Kilogramme,	Weight of one cubic decimeter of water of the temperature of 39° 12′ Fahrenheit.	=	2·6803 lbs. troy. 2·5055 lbs. avoirdupois.
Hectogramme,	$\frac{1}{10}$th of kilogramme - - - -	=	3·2 ounces troy. 3·52 ounces avoirdupois.
Decagramme,	$\frac{1}{100}$th of kilogramme - - - -	=	6·43 dwts. troy.
Gramme,	$\frac{1}{1000}$th of kilogramme - - - -	=	15·438 grains troy. 0·643 pennyweight. 0·032 ounce troy.
Decigramme,	$\frac{1}{10000}$th of kilogramme - - - -	=	1·5438 grain troy.

The following table exhibits the proportion of weights in the principal places of Europe to 100 lbs. English avoirdupois.

100 lbs. English	=	91 lbs.	8 oz.	for the pound of	Amsterdam, Paris (old), &c.
—	=	96	8	—	Antwerp or Brabant.
—	=	88	0	—	Rouen (the Viscounty weight).
—	=	106	0	—	Lyons (the city weight).
—	=	90	9	—	Rochelle.
—	=	107	11	—	Toulouse and Upper Languedoc.
—	=	113	0	—	Marseilles or Provence.
—	=	81	7	—	Geneva.
—	=	93	5	—	Hamburgh.
—	=	89	7	—	Frankfort, &c.
—	=	96	1	—	Leipsic, &c.
—	=	137	4	—	Genoa.
—	=	132	1	—	Leghorn.
—	=	153	11	—	Milan.
—	=	152	0	—	Venice.
—	=	154	10	—	Naples.
—	=	97	0	—	Seville, Cadiz, &c.
—	=	104	13	—	Portugal.
—	=	96	5	—	Liege.
—	=	112	$0\frac{3}{8}$	—	Russia.
—	=	107	$0\frac{1}{4}$	—	Sweden.
—	=	89	$0\frac{3}{8}$	—	Denmark.

The Paris pound (poids de marc of Charlemagne) contained 9216 Paris grains; it was divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English troy grains.

The English troy pound of 12 ounces contains 5760 troy grains = 7021 Paris grains. The English avoirdupois pound of 16 ounces contains 7000 English troy grains, and is equal to 8538 Paris grains.

To reduce Paris grains to English troy grains, divide by } 1·2189.
Or, to reduce English troy grains to Paris grains, multiply by }
To reduce Paris ounces to English troy, divide by } 1·015734.
To reduce English troy ounces to Paris, multiply by }

Weights of a Sash are two weights by which the sash is suspended and kept in the situation to which it is raised by means of cords passing over pulleys. The vertical sides of the sash frames are generally made hollow in order to receive the weights, which, by this means are entirely concealed. Thus, to keep the sash in suspension, each weight must be half the weight of the sash. The cords should be of good quality, or they soon fret to pieces.

Welch Groins. A groin formed by the intersection of two cylindrical vaults, one whereof is of less height than the other.

Well. A deep circular pit, or sort of shaft, sunk by digging down through the different strata or beds of earthy or other materials of the soil, so as to form an excavation for the purpose of containing the water of some spring or internal reservoir, by which it may be supplied.

Well-hole. In a flight of stairs, the space left in the middle beyond the ends of the steps.

Weston. See Architects, list of, 137.

Wheel. (Sax.) In mechanics, an engine consisting of a circular body turning on an axis, for enabling a given power to move or overcome a given weight or resistance. This machine may be referred to the lever.

Wheel Window. In Gothic architecture, a circular window, with radiating mullions, resembling the disposition of the spokes of a wheel.

Whetstone. A stone of fine quality by which tools for cutting wood are brought to a fine edge, after being ground upon a gritstone, or grinding-stone, to a rough edge.

White Lead. A material forming the basis of most colours in house-painting. The common method of making it is by rolling up thin leaden plates spirally, so as to leave the space of about an inch between each coil. These are placed vertically in earthen pots, at the bottom of which is some good vinegar. The pots are covered, and exposed for a length of time to a gentle heat in a sandbath, or by bedding them in dung. The vapour of the vinegar, assisted by the tendency of lead to combine with the oxygen which is present, corrodes the lead, and converts the external portion into a white substance which comes off in flakes. These are washed and dried in stoves in lumps, and form the white lead of the painters.

Wicket. A small door made in a gate.

William of Sens. See Architects, list of, 100.

William of Wykeham. See Architects, list of, 141.

Wind-beam. An obsolete name for a Collar-beam.

Windlass or Windlace. A machine for raising weights, in which a rope or chain is wound about a cylindrical body moved by levers; also a handle by which anything is turned.

Window. An aperture in a wall for the transmission of light to an apartment. See Book III. Chap. I. Sect. 20.

Wine Cellar. The apartment on the basement story, under ground, for stowing wine. The most important point in its construction is its being kept at a cool equal temperature. See Binns.

Wire. A small flexible bar of metal, elongated by means of a machine called a draw-bench.

With. (Sax.) The partition between two chimney flues. See Chimney.

Wood. (Sax.) A fibrous material much used in building, and formed into shape by edge tools. The different sorts in use form the subject of Sect. 4. Chap. II. Book II.

Wood Bricks. Blocks of wood cut to the form and size of bricks, inserted in the interior walls as holds for the joinery.

Working Drawings. See Book II. Chap. IV. Sect. 4.

Wotton, Sir Henry. See Architects, list of, 251.

Wreathed Columns. Those which are twisted in the form of a screw, also very appropriately called contorted columns.

Wren. See Architects, list of, 264.

X.

Xenodochium. (Gr. Ξενος, a guest, and Δεχομαι, to receive.) A name given by the ancients to a building for the reception of strangers.

Xystus. (Gr.) In ancient architecture, a spacious portico, wherein the athletæ exercised themselves during winter. The Romans called, on the contrary, their *hypæthral* walks xysti, which walks were by the Greeks called περιδρομιδες.

Y.

Yard. A well known measure of three feet.

Z.

Zax. An instrument used for cutting slates.

Zigzag Moulding. An ornament used in Gothic architecture. See p.174.

Zinc. A metal now much used in building. See Book II. Chap. II. Sect. 7.

Zocco. (It.) The same as Socle, which see.

Zophorus. The same as Frieze, which see.

Zotheca. A small room or alcove, which might be added to, or separated from, the room to which it adjoined.

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⁂ *The figures refer to the several paragraphs.*

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